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(54) PERFORMANCE OF DEDUPLICATION STORAGE SYSTEMS

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G06F 3/06 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 3/065*** (2013.01); ***G06F 3/067*** (2013.01); ***G06F 3/0608*** (2013.01); ***G06F 3/0619*** (2013.01); ***G06F 3/0641*** (2013.01)

(58) **Field of Classification Search**
CPC .. G06F 11/1448; G06F 11/1453; G06F 3/065; G06F 3/0619; G06F 3/0641; G06F 3/067; G06F 3/0608
USPC 711/162
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,478,113	B1 *	1/2009	De Spiegeleer	G06F 11/1453
7,685,171	B1 *	3/2010	Beaverson	G06F 11/1451 707/999.202
8,904,125	B1 *	12/2014	Elling	G06F 11/1451 711/162
8,983,952	B1 *	3/2015	Zhang	G06F 11/1453 707/736
9,501,365	B2 *	11/2016	Parab	G06F 11/1453
2011/0161291	A1 *	6/2011	Taleck	G06F 17/30156 707/622
2011/0161297	A1 *	6/2011	Parab	G06F 17/30156 707/646
2012/0084261	A1 *	4/2012	Parab	G06F 11/1453 707/654
2012/0233345	A1 *	9/2012	Hannuksela	H04N 21/26258 709/231

OTHER PUBLICATIONS

Upadhyay, A. et al, "Deduplication and Compression Techniques in Cloud Design", IEEE International Systems Conference SysCon 2012 (pp. 1-6).*

* cited by examiner

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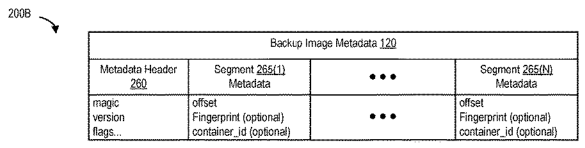
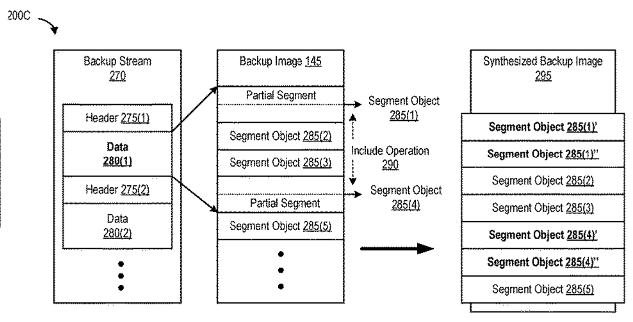
(57) **ABSTRACT**

Disclosed herein are methods, systems, and processes to improve backup and restore performance in deduplication storage environments. A metadata stream that includes data segment offsets that are associated with data segments of a previous backup image and indicate data segment boundaries is received. An offset for an include operation is determined. The include operation references one or more data segments, and is part of a request to perform a backup operation. The backup operation is performed by modifying the include operation, if the offset involves one or more partial data segments.

17 Claims, 14 Drawing Sheets





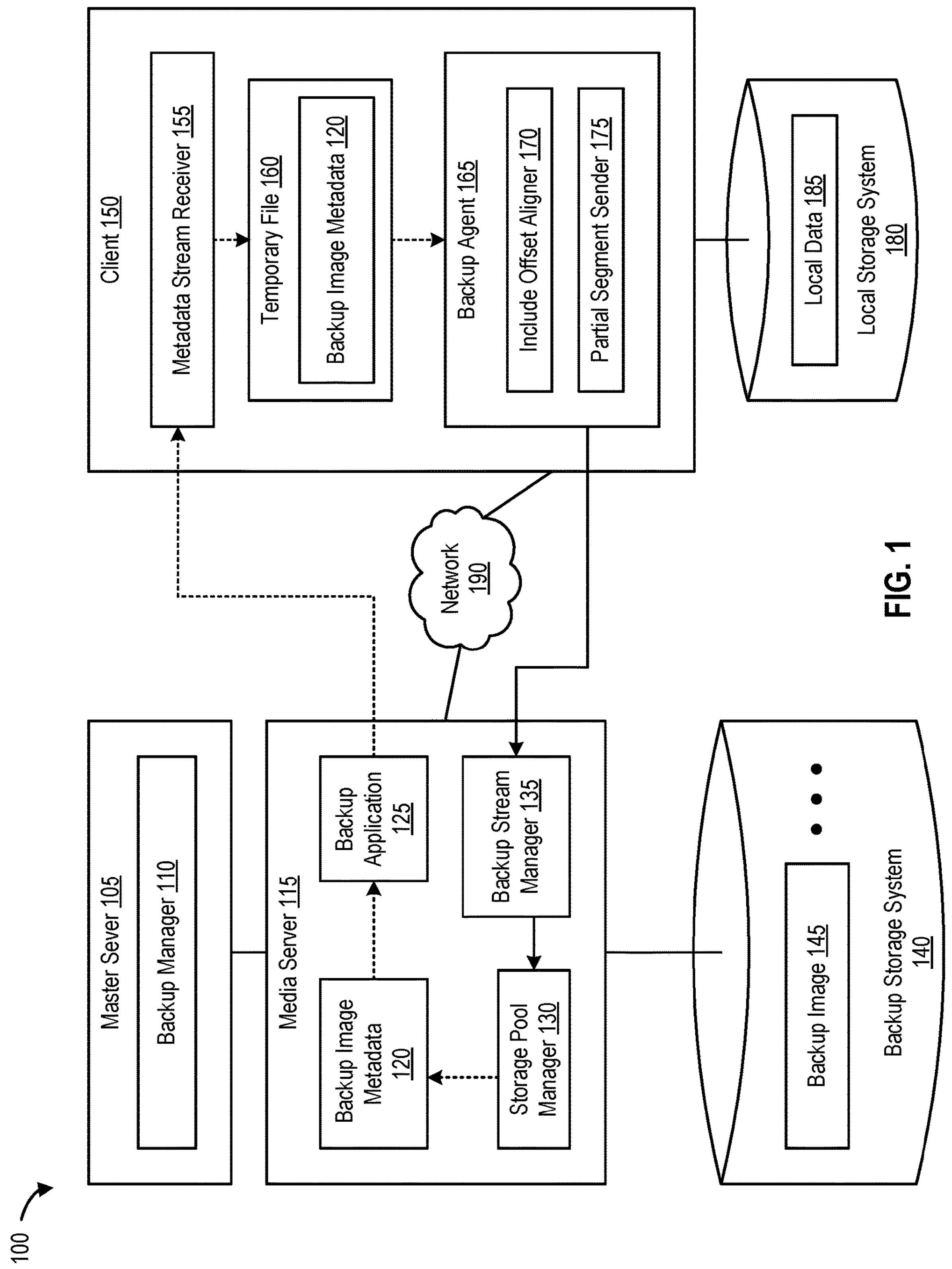

100
Master Sever 105
Backup Manager 110
Media Server 115
Backup Image Metadata 120
Backup Application 125
Storage Pool Manager 130
Backup Stream Manager 135
Backup Storage System 140
Backup Image 145
Network 190
Client 150
Metadata Stream Receiver 155
Temporary File 160
Backup Image Metadata 120
Backup Agent 165
Include Offset Aligner 170
Partial Segment Sender 175
Local Storage System 180
Local Data 185

FIG. 1

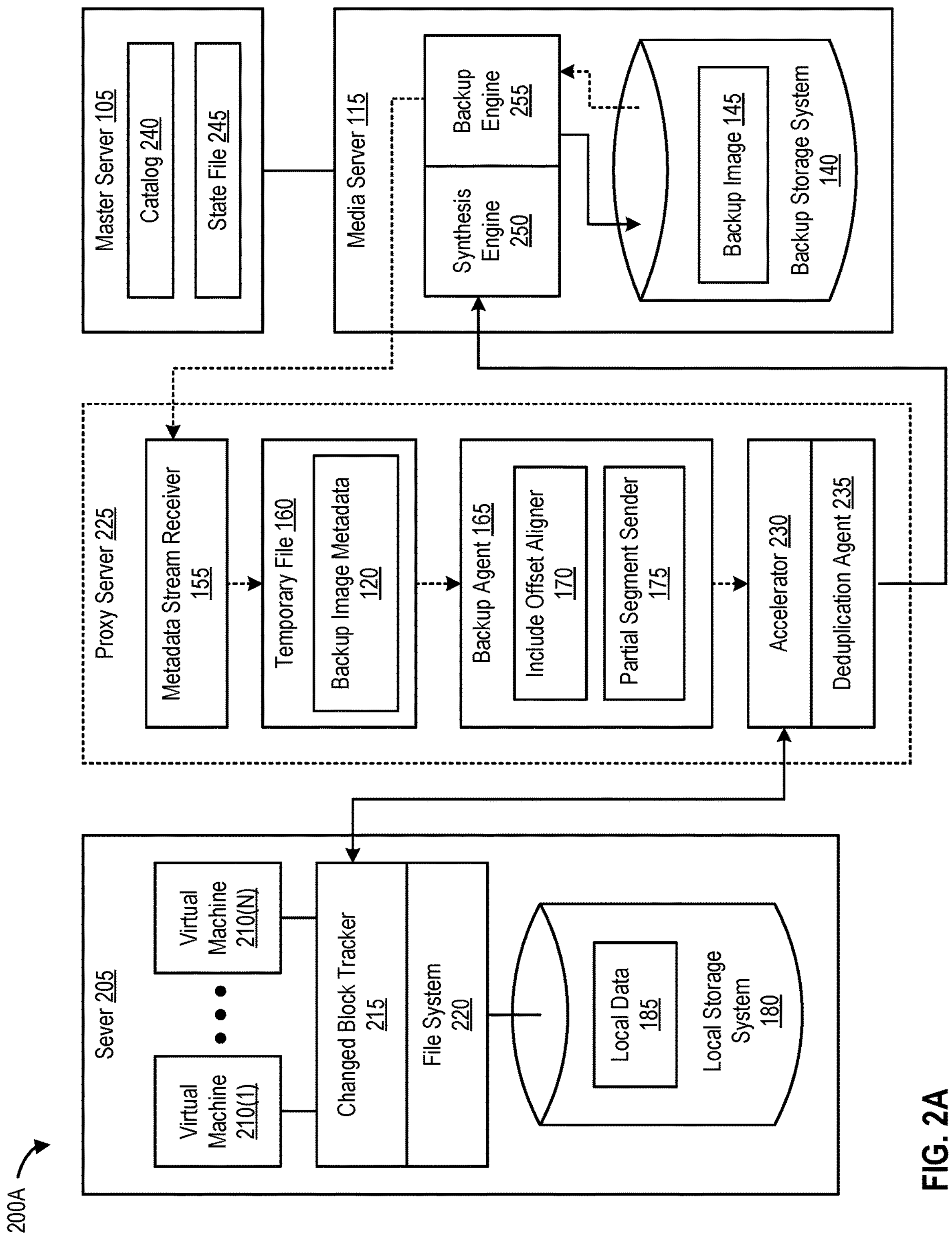

200A
Master Server 105
Catalog 240
State File 245
Media Server 115
Synthesis Engine 250
Backup Engine 255
Backup Image 145
Backup Storage System 140
Proxy Server 225
Metadata Stream Receiver 155
Temporary File 160
Backup Image Metadata 120
Backup Agent 165
Include Offset Aligner 170
Partial Segment Sender 175
Accelerator 230
Deduplication Agent 235
Sever 205
Virtual Machine 210(1)
Virtual Machine 210(N)
Changed Block Tracker 215
File System 220
Local Data 185
Local Storage System 180

FIG. 2A

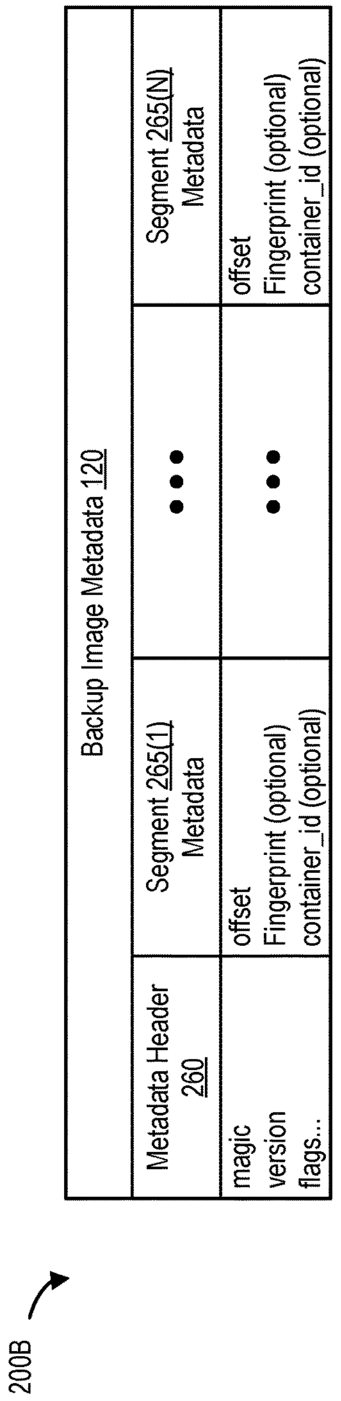

200B
Backup Image Metadata 120
Metadata Header 260
magic
version
flags...
Segment 265(1) Metadata
offset
Fingerprint (optional)
container_id (optional)
• • •
• • •
Segment 265(N) Metadata
offset
Fingerprint (optional)
container_id (optional)

FIG. 2B

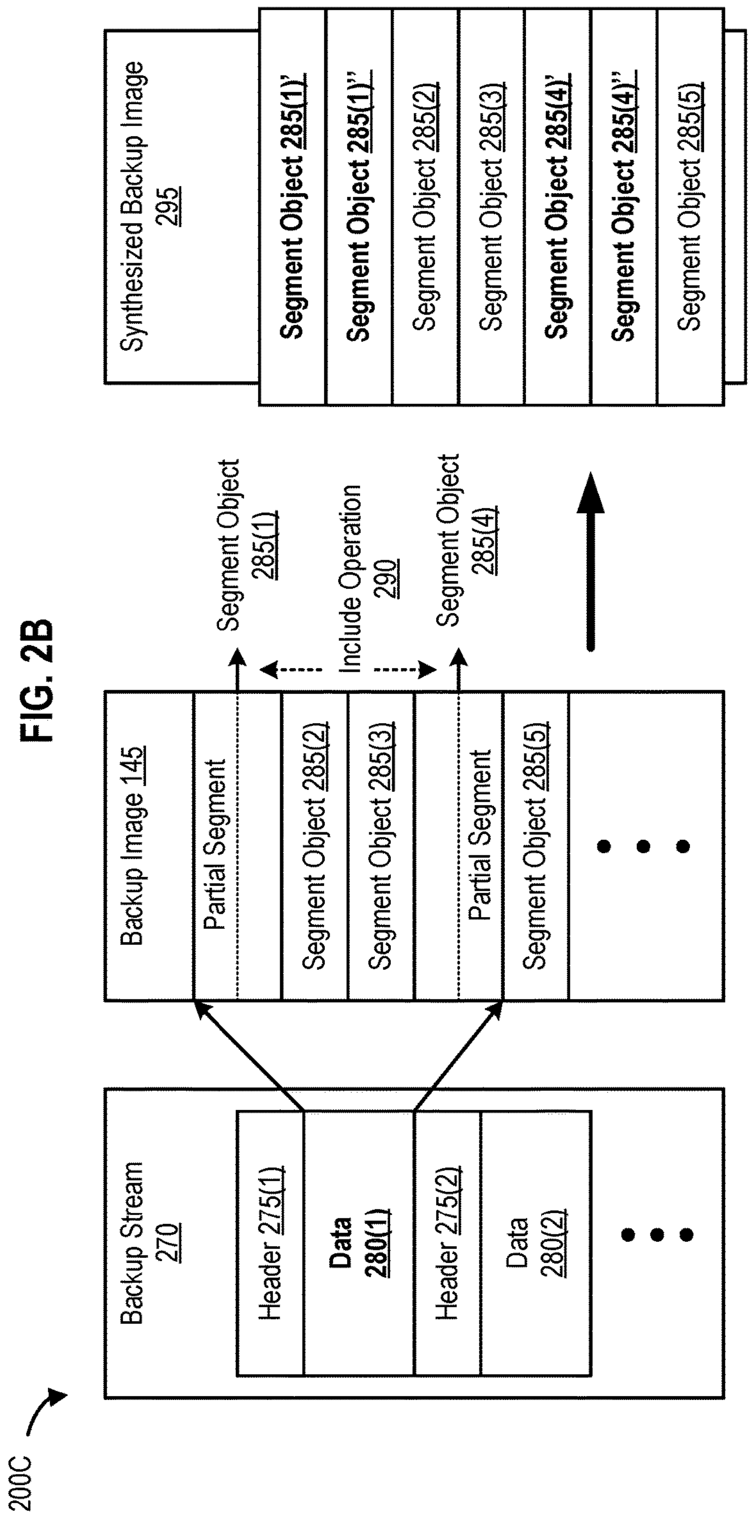

200C
Backup Stream 270
Header 275(1)
Data 280(1)
Header 275(2)
Data 280(2)
• • •
Backup Image 145
Partial Segment
Segment Object 285(2)
Segment Object 285(3)
Partial Segment
Segment Object 285(5)
• • •
Segment Object 285(1)
Include Operation 290
Segment Object 285(4)
Synthesized Backup Image 295
Segment Object 285(1)'
Segment Object 285(1)''
Segment Object 285(2)
Segment Object 285(3)
Segment Object 285(4)'
Segment Object 285(4)''
Segment Object 285(5)

FIG. 2C

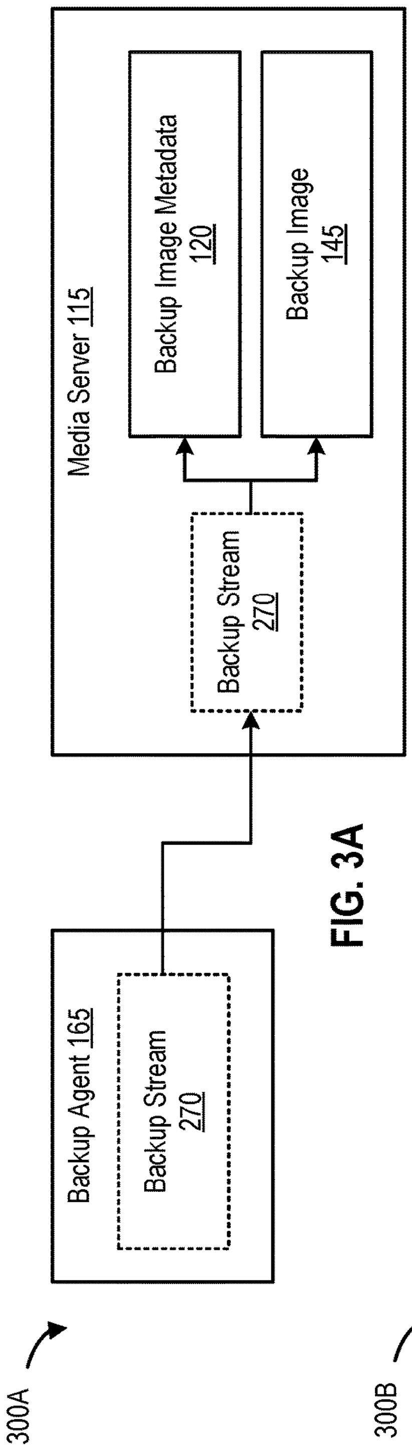


FIG. 3A

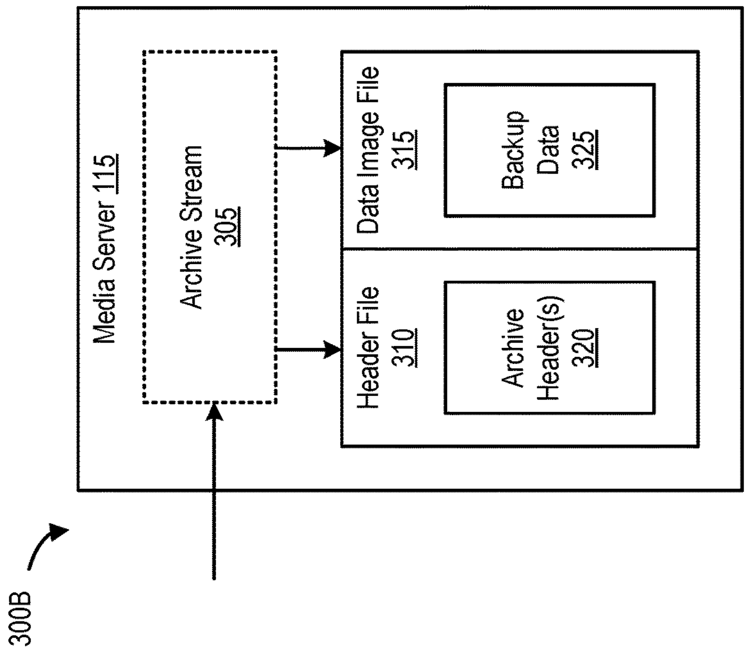


FIG. 3B

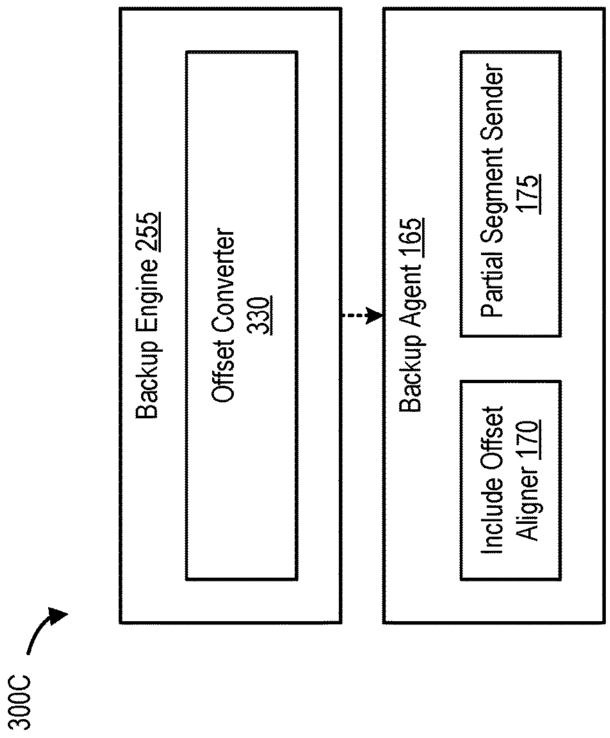


FIG. 3C

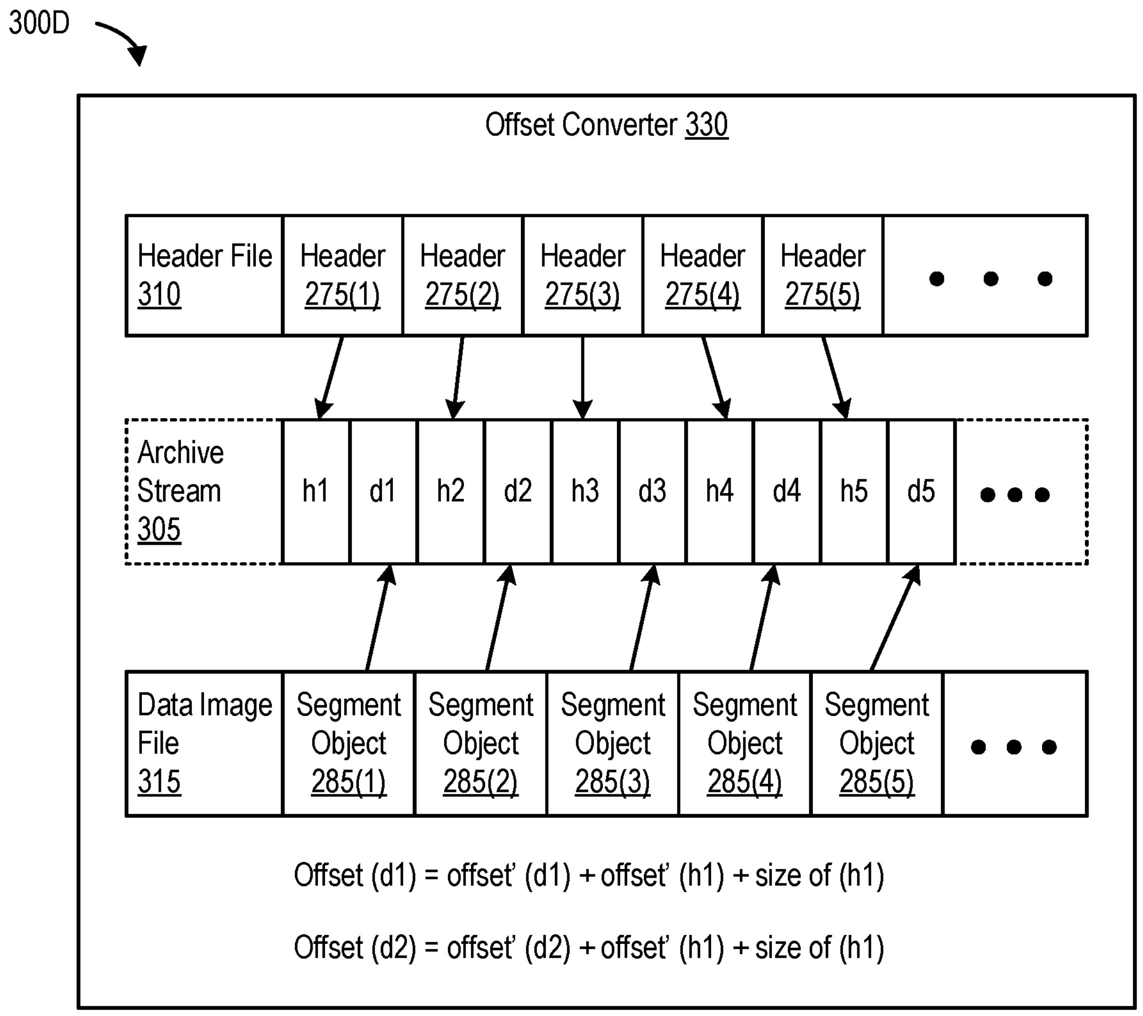

300D
Offset Converter 330
Header File 310
Header 275(1)
Header 275(2)
Header 275(3)
Header 275(4)
Header 275(5)
Archive Stream 305
h1
d1
h2
d2
h3
d3
h4
d4
h5
d5
Data Image File 315
Segment Object 285(1)
Segment Object 285(2)
Segment Object 285(3)
Segment Object 285(4)
Segment Object 285(5)
Offset (d1) = offset' (d1) + offset' (h1) + size of (h1)
Offset (d2) = offset' (d2) + offset' (h1) + size of (h1)

FIG. 3D

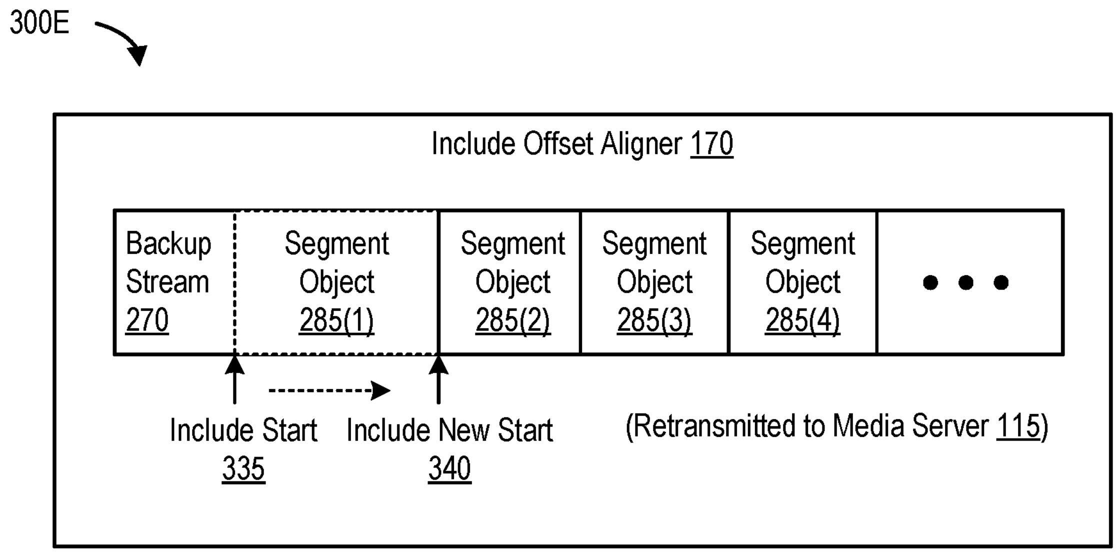

300E
Include Offset Aligner 170
Backup Stream 270
Segment Object 285(1)
Segment Object 285(2)
Segment Object 285(3)
Segment Object 285(4)
Include Start 335
Include New Start 340
(Retransmitted to Media Server 115)

FIG. 3E

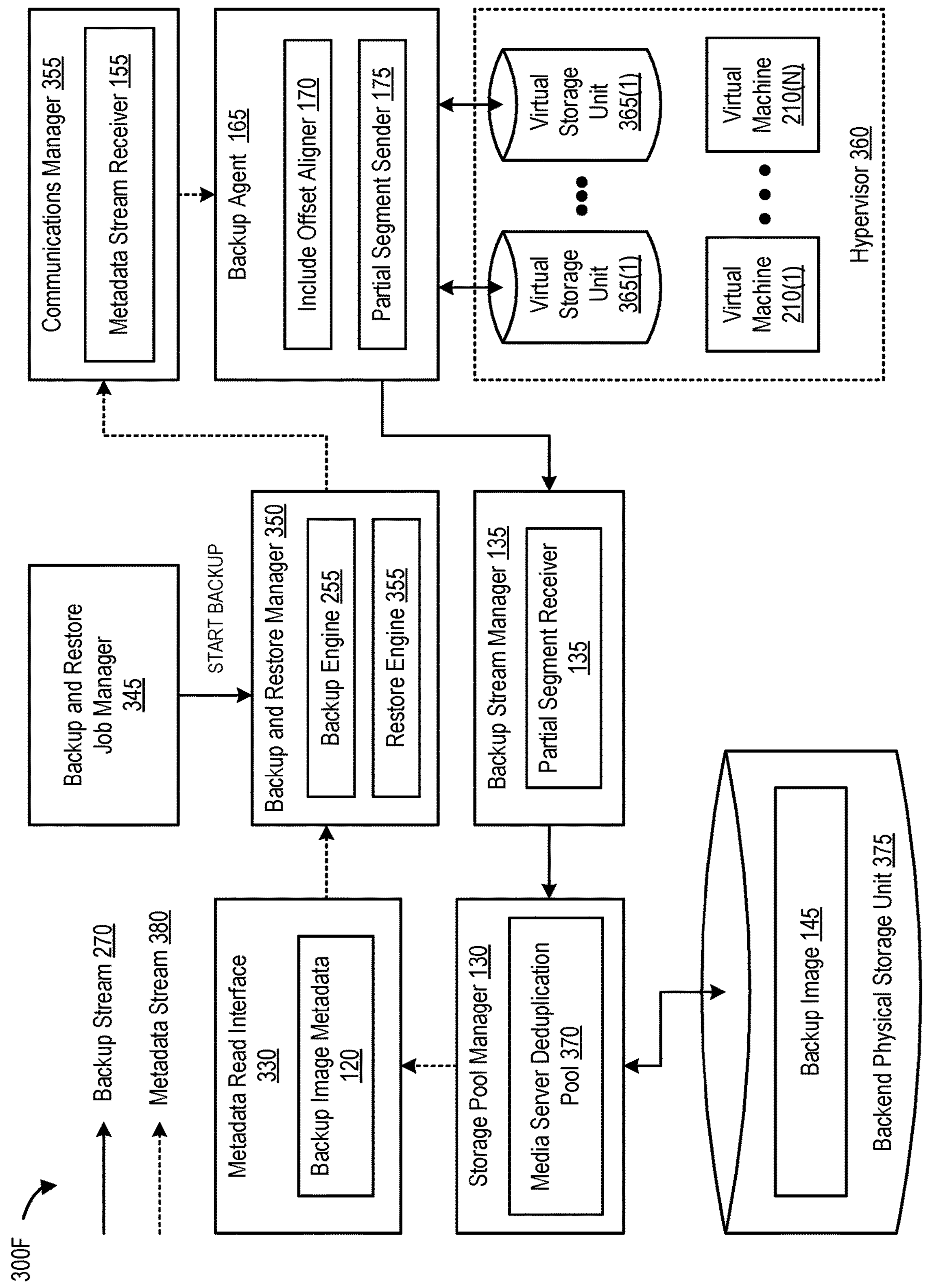
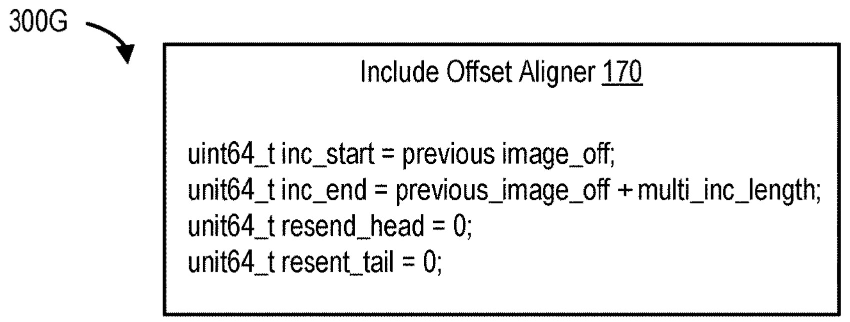

300F
Backup Stream 270
Metadata Stream 380
Backup and Restore Job Manager 345
START BACKUP
Backup and Restore Manager 350
Backup Engine 255
Restore Engine 355
Communications Manager 355
Metadata Stream Receiver 155
Backup Agent 165
Include Offset Aligner 170
Partial Segment Sender 175
Virtual Storage Unit 365(1)
Virtual Storage Unit 365(1)
Virtual Machine 210(1)
Virtual Machine 210(N)
Hypervisor 360
Backup Stream Manager 135
Partial Segment Receiver 135
Metadata Read Interface 330
Backup Image Metadata 120
Storage Pool Manager 130
Media Server Deduplication Pool 370
Backup Image 145
Backend Physical Storage Unit 375

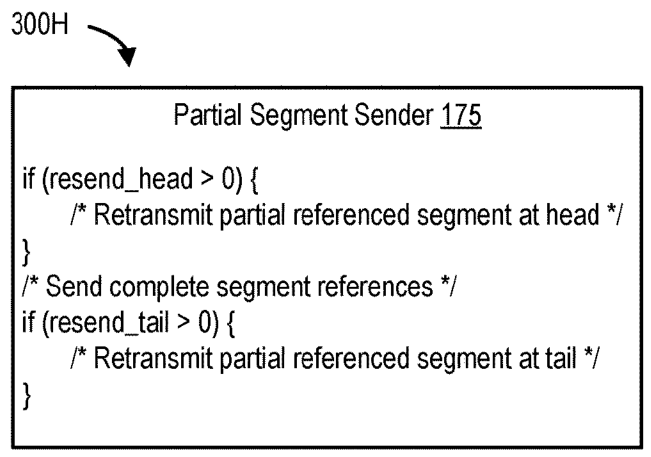
FIG. 3F



```
Include Offset Aligner 170

uint64_t inc_start = previous image_off;
unit64_t inc_end = previous_image_off + multi_inc_length;
unit64_t resend_head = 0;
unit64_t resent_tail = 0;
```

FIG. 3G



```
Partial Segment Sender 175

if (resend_head > 0) {
      /* Retransmit partial referenced segment at head */
}
/* Send complete segment references */
if (resend_tail > 0) {
      /* Retransmit partial referenced segment at tail */
}
```

FIG. 3H

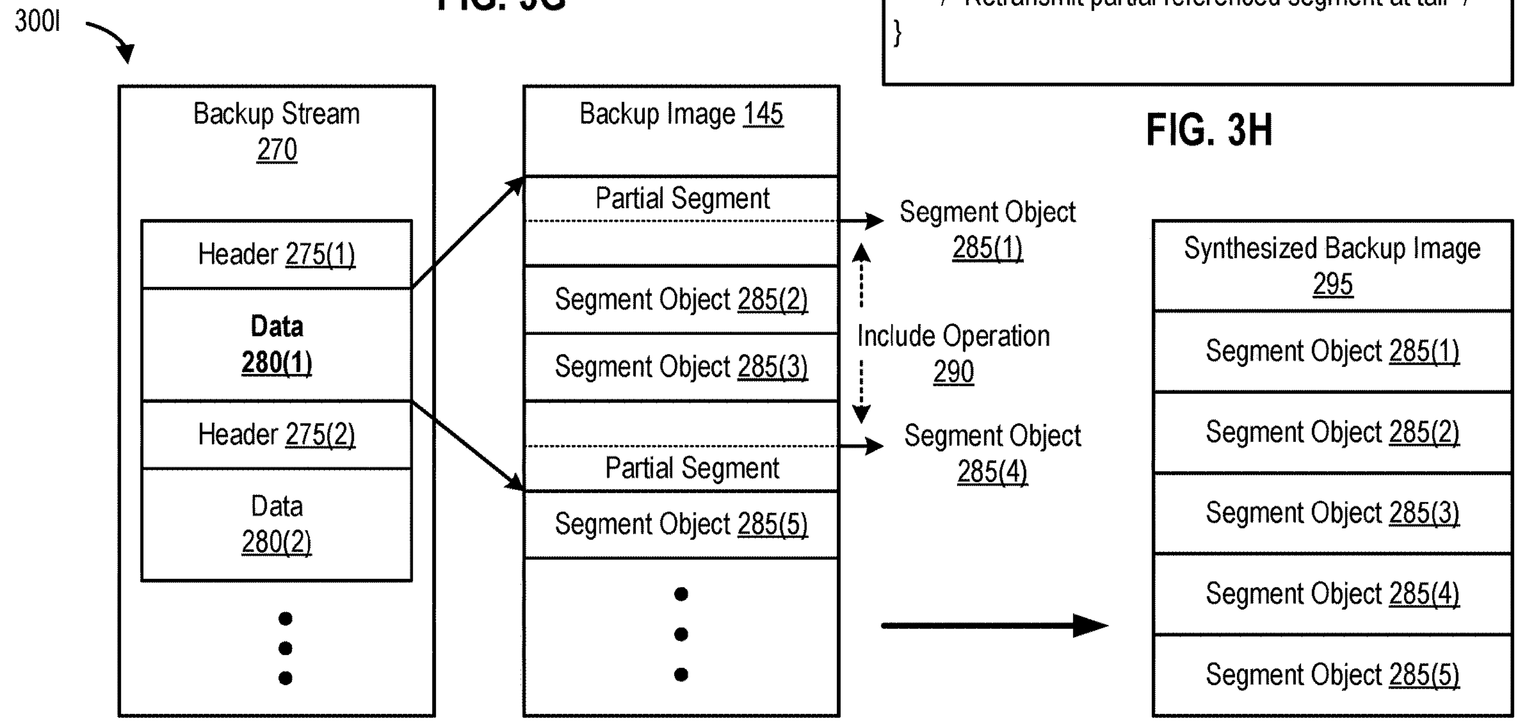


FIG. 3I

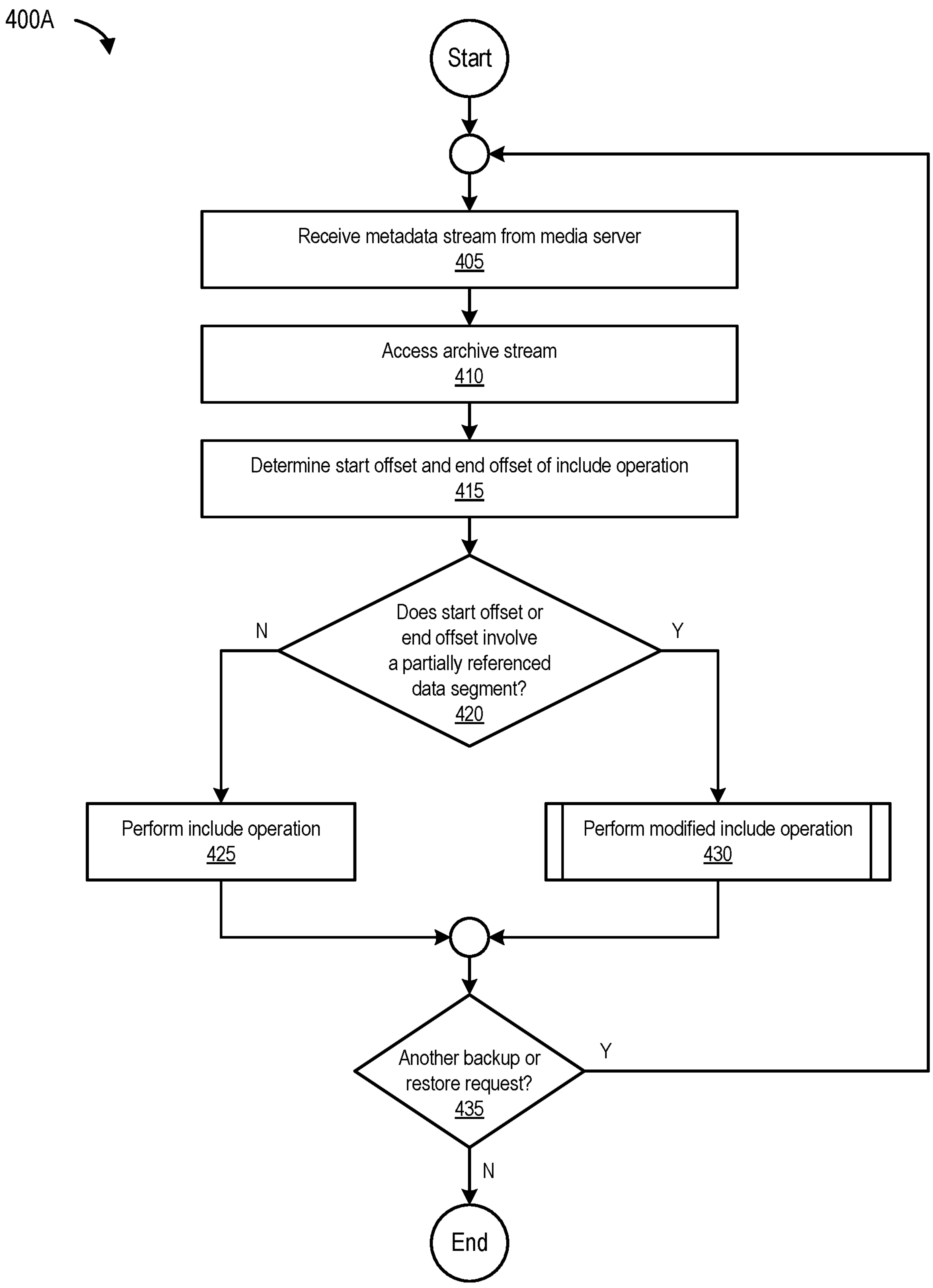

400A
Start
Receive metadata stream from media server 405
Access archive stream 410
Determine start offset and end offset of include operation 415
Does start offset or end offset involve a partially referenced data segment? 420
N
Y
Perform include operation 425
Perform modified include operation 430
Another backup or restore request? 435
Y
N
End

FIG. 4A

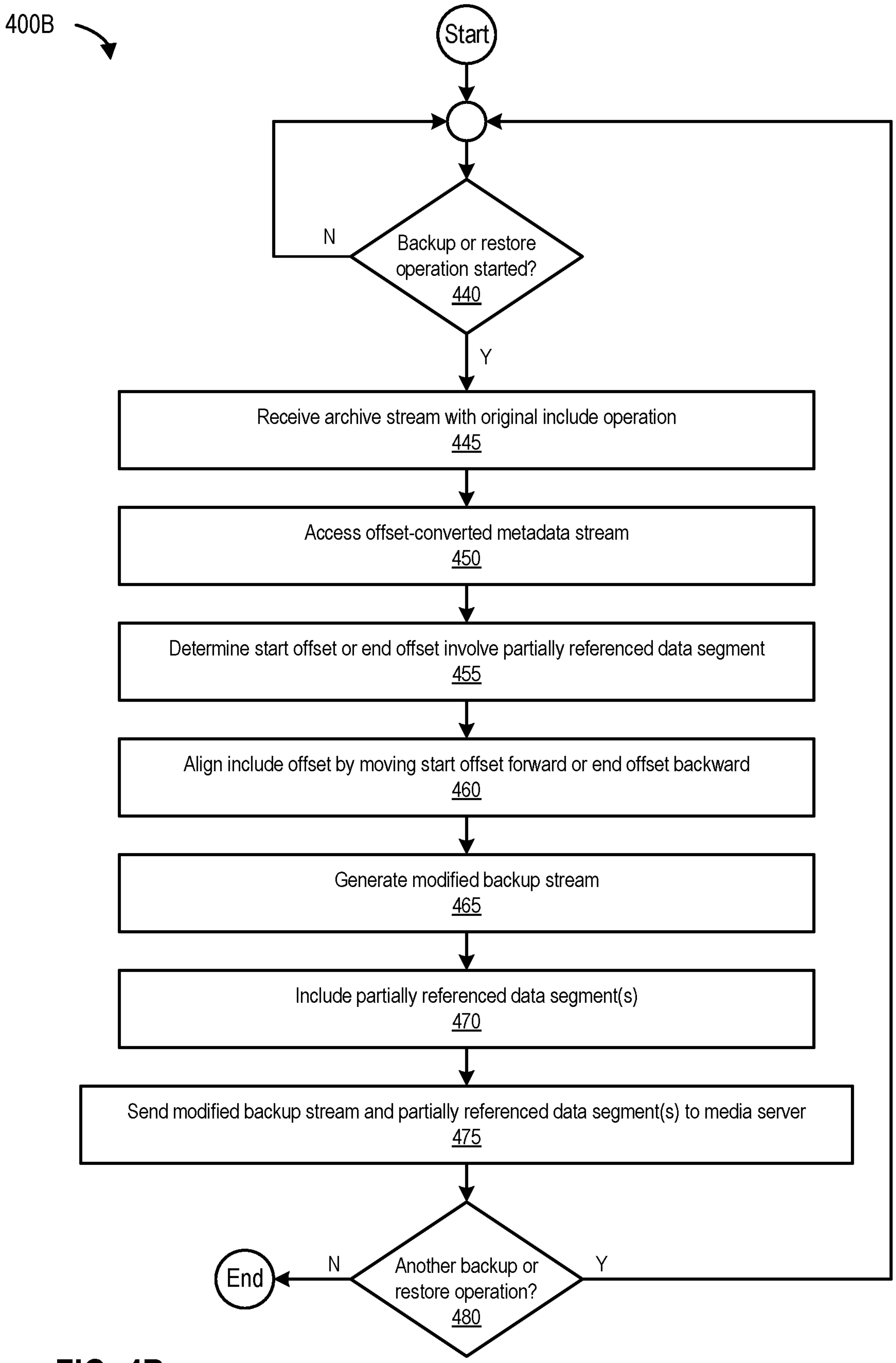

400B
Start
Backup or restore operation started? 440
N
Y
Receive archive stream with original include operation 445
Access offset-converted metadata stream 450
Determine start offset or end offset involve partially referenced data segment 455
Align include offset by moving start offset forward or end offset backward 460
Generate modified backup stream 465
Include partially referenced data segment(s) 470
Send modified backup stream and partially referenced data segment(s) to media server 475
Another backup or restore operation? 480
N
Y
End

FIG. 4B

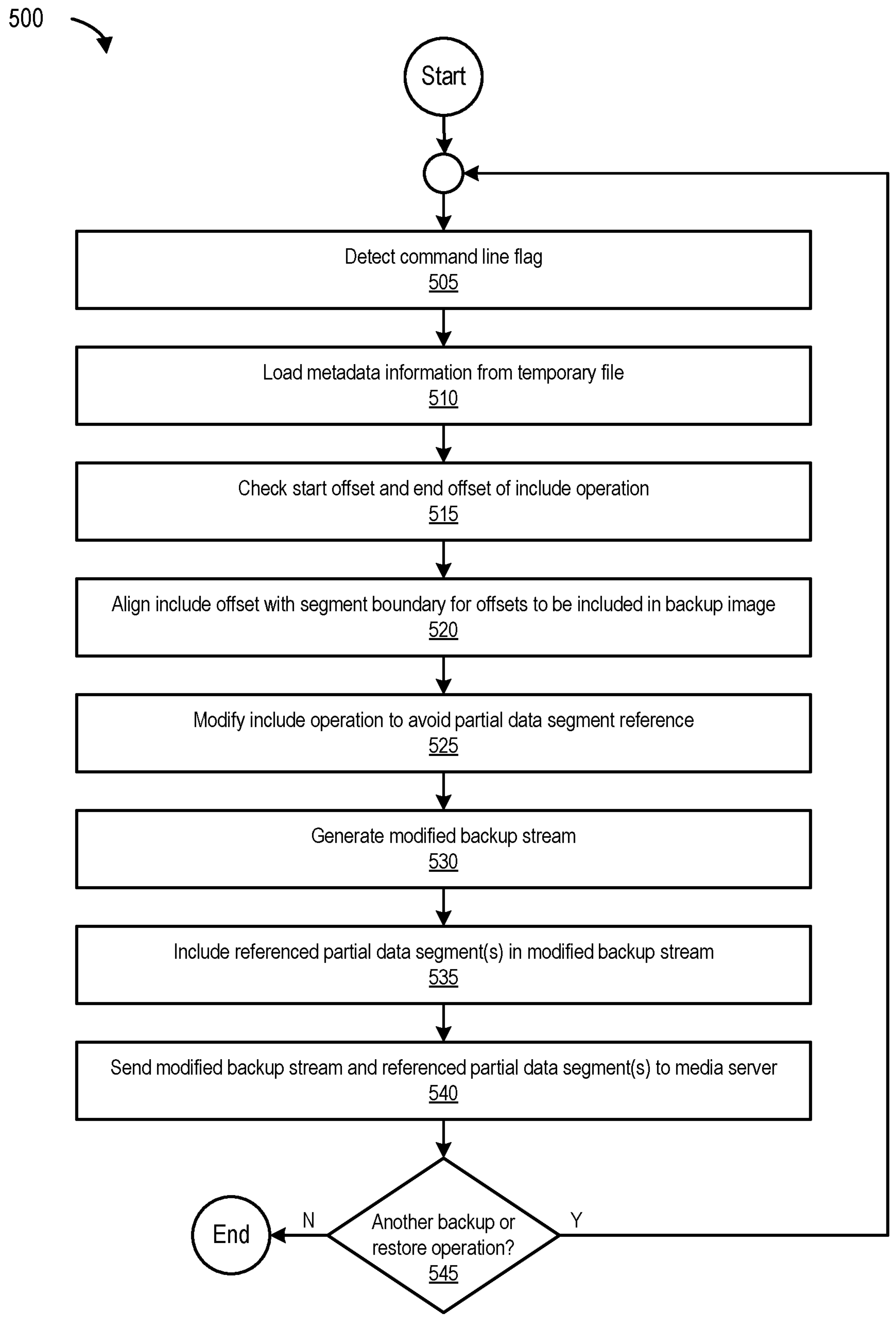

500
Start
Detect command line flag
505
Load metadata information from temporary file
510
Check start offset and end offset of include operation
515
Align include offset with segment boundary for offsets to be included in backup image
520
Modify include operation to avoid partial data segment reference
525
Generate modified backup stream
530
Include referenced partial data segment(s) in modified backup stream
535
Send modified backup stream and referenced partial data segment(s) to media server
540
Another backup or restore operation?
545
Y
N
End

FIG. 5

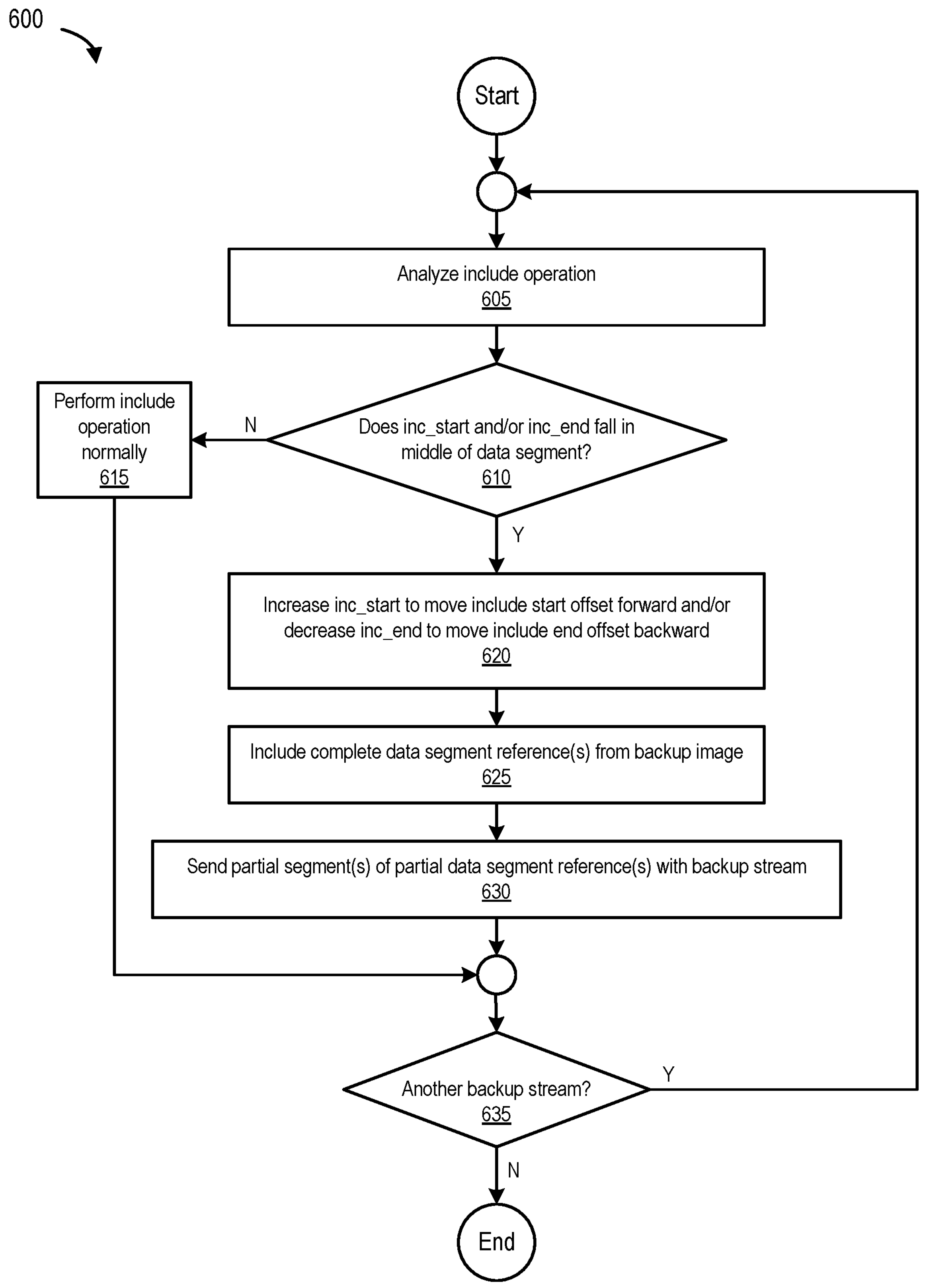

600
Start
Analyze include operation
605
Does inc_start and/or inc_end fall in middle of data segment?
610
N
Perform include operation normally
615
Y
Increase inc_start to move include start offset forward and/or decrease inc_end to move include end offset backward
620
Include complete data segment reference(s) from backup image
625
Send partial segment(s) of partial data segment reference(s) with backup stream
630
Another backup stream?
635
Y
N
End

FIG. 6

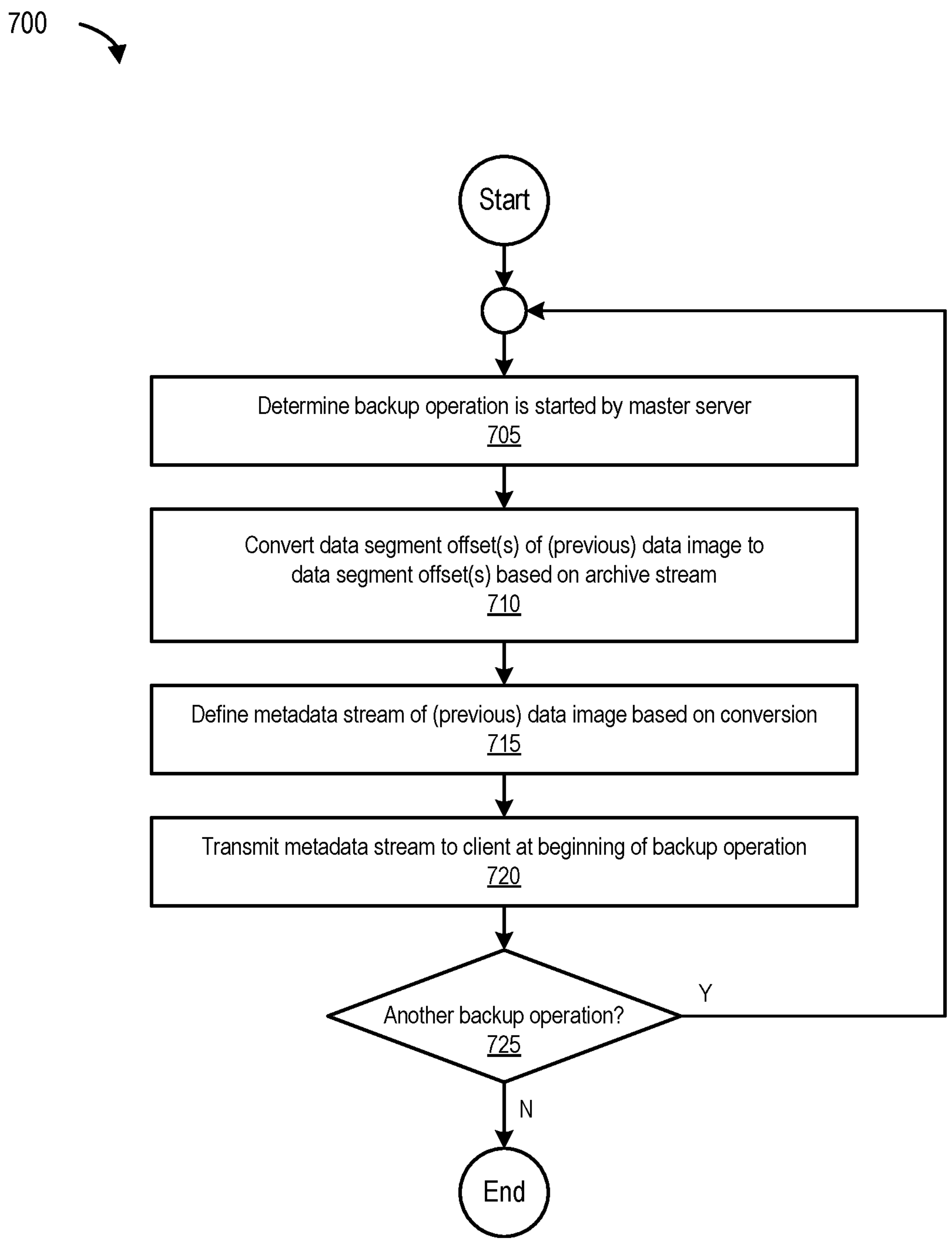

700
Start
Determine backup operation is started by master server
705
Convert data segment offset(s) of (previous) data image to data segment offset(s) based on archive stream
710
Define metadata stream of (previous) data image based on conversion
715
Transmit metadata stream to client at beginning of backup operation
720
Another backup operation?
725
Y
N
End

FIG. 7

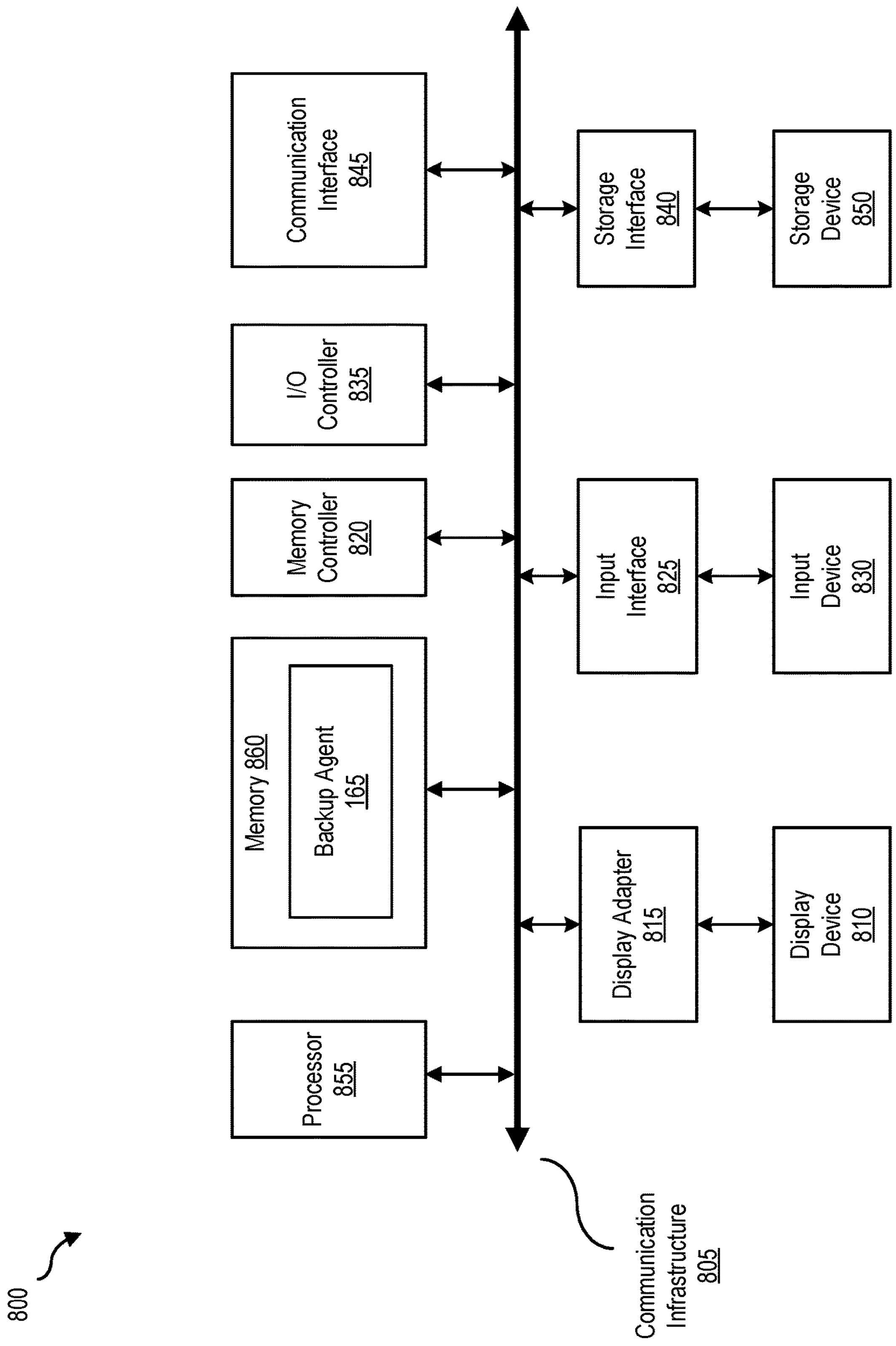

800
Processor 855
Memory 860
Backup Agent 165
Memory Controller 820
I/O Controller 835
Communication Interface 845
Display Adapter 815
Input Interface 825
Storage Interface 840
Display Device 810
Input Device 830
Storage Device 850
Communication Infrastructure 805

FIG. 8

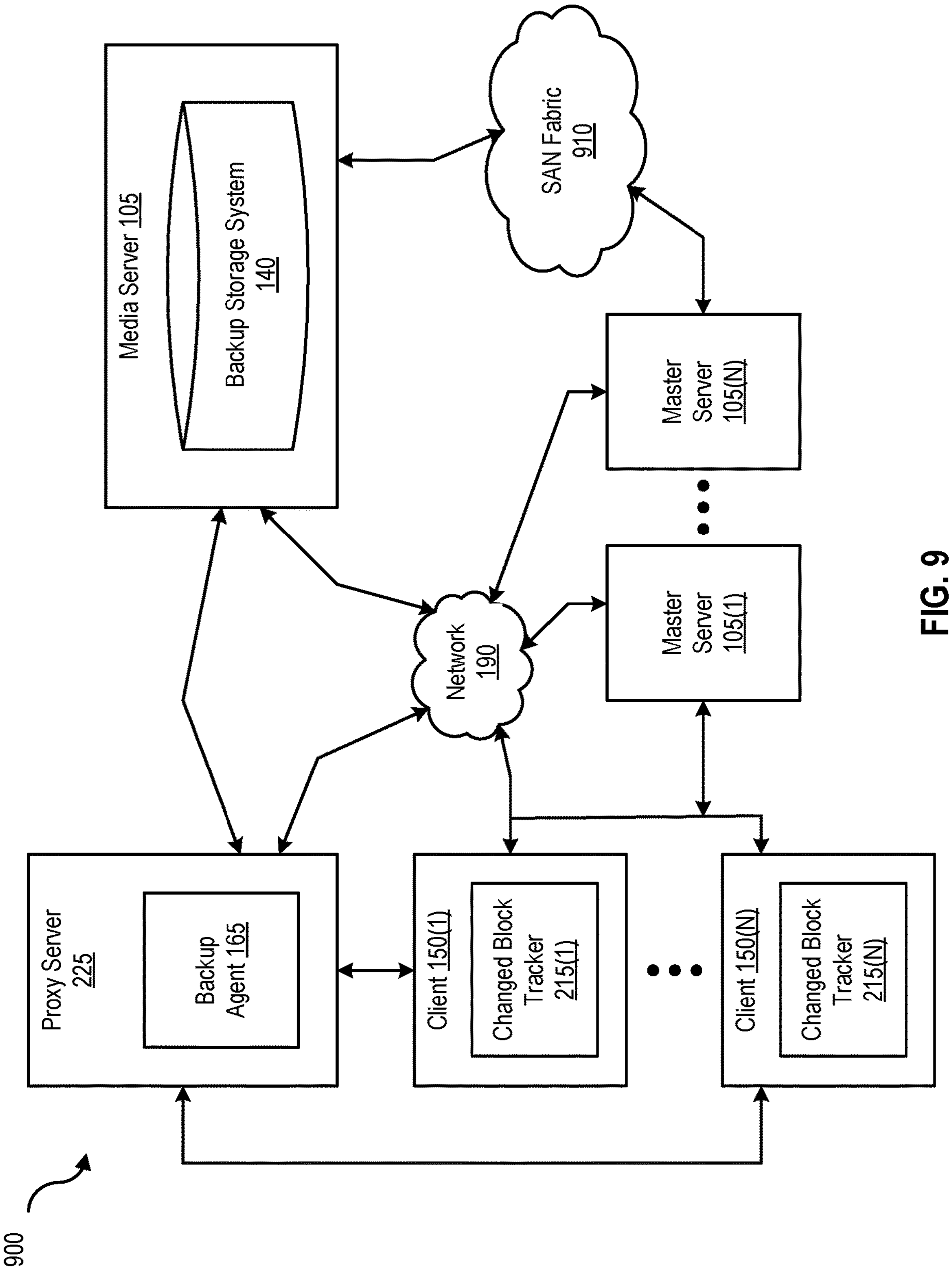

900
Media Server 105
Backup Storage System 140
SAN Fabric 910
Network 190
Master Server 105(1)
Master Server 105(N)
Proxy Server 225
Backup Agent 165
Client 150(1)
Changed Block Tracker 215(1)
Client 150(N)
Changed Block Tracker 215(N)

FIG. 9

PERFORMANCE OF DEDUPLICATION STORAGE SYSTEMS

FIELD OF THE DISCLOSURE

The present disclosure relates to improving backup and restore performance in deduplication storage environments.

DESCRIPTION OF THE RELATED ART

A synthetic backup operation consolidates a baseline full backup set and several incremental backup sets into a new full backup set. The new full backup set can then be used for further incremental backup operations. Generally, a new full backup of a given data set is preferable to definitively protect the data set in question.

The speed of a synthetic backup operation can be improved by combining changed data with a list of data that has already been backed up during a previous full or incremental backup operation, and deduplicating this combination of data—without reading backup images and/or creating a new backup image. Therefore, by independently tracking and deduplicating data that has already been backed up, such a system only requires changed data to create a synthetic full backup set, for example, in roughly the same time it takes to run an incremental backup operation.

Unfortunately, including partial segments of changed data (e.g., as part of an include operation) to create a synthetic full backup set (e.g., partial segment inclusion) degrades synthetic backup and restore performance in deduplication storage environments.

SUMMARY OF THE DISCLOSURE

Disclosed herein are methods, systems, and processes to improve backup and restore performance in deduplication storage environments. One such method involves receiving a metadata stream that includes data segment offsets that are associated with data segments of a previous backup image, and indicate data segment boundaries. The method determines an offset for an include operation. The offset is a start offset or an end offset. The include operation references one or more data segments, and is part of a request to perform a backup operation. The method then performs the backup operation by modifying the include operation, if the offset involves one or more partial data segments.

In one embodiment, the method aligns the offset of the include operation with a data segment boundary by moving the start offset forward from a first data segment if the first data segment includes a partial data segment, and/or moving the end offset backward from a second data segment if the second data segment includes another partial data segment.

In another embodiment, performing the modified include operation as part of the backup operation includes generating a modified backup stream, and transmitting the partial data segment instead of the first data segment to a media server as part of the modified backup stream if the first data segment includes the partial data segment, and/or transmitting another partial data segment instead of the second data segment to the media server as part of the modified backup stream if the second data segment includes another partial data segment.

The foregoing is a summary and thus contains, by necessity, simplifications, generalizations and omissions of detail; consequently those skilled in the art will appreciate that the summary is illustrative only and is not intended to be in any limiting. Other aspects, features, and advantages of the present disclosure, as defined solely by the claims, will become apparent in the non-limiting detailed description set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure may be better understood, and its numerous objects, features, and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

FIG. **1** is a block diagram **100** of a deduplication storage system, according to one embodiment of the present disclosure.

FIG. **2**A is a block diagram **200**A of a computing system that performs client-side deduplication, according to one embodiment of the present disclosure.

FIG. **2**B is a table **200**B of backup image metadata, according to one embodiment of the present disclosure.

FIG. **2**C is a block diagram **200**C of a deduplication storage system that performs partial segment inclusion, according to one embodiment of the present disclosure.

FIG. **3**A is a block diagram **300**A of a backup agent and a media server, according to one embodiment of the present disclosure.

FIG. **3**B is a block diagram **300**B of a media server, according to one embodiment of the present disclosure.

FIG. **3**C is a block diagram **300**C of a backup engine and a backup agent, according to one embodiment of the present disclosure.

FIG. **3**D is a block diagram **300**D of an offset converter, according to one embodiment of the present disclosure.

FIG. **3**E is a block diagram **300**E of an include offset aligner, according to one embodiment of the present disclosure.

FIG. **3**F is a block diagram **300**F a deduplication storage system, according to one embodiment of the present disclosure.

FIG. **3**G is a block diagram **300**G of an include offset aligner, according to one embodiment of the present disclosure.

FIG. **3**H is a block diagram **300**H of a partial segment sender, according to one embodiment of the present disclosure.

FIG. **3**I is a block diagram **300**I of a deduplication storage system that avoids partial segment inclusion, according to one embodiment of the present disclosure.

FIG. **4**A is a flowchart **400**A of a process for identifying a partially referenced data segment, according to one embodiment of the present disclosure.

FIG. **4**B is a flowchart **400**B of a process for avoiding partial segment inclusion, according to one embodiment of the present disclosure.

FIG. **5** is a flowchart **400** of a process for generating a modified backup stream, according to one embodiment of the present disclosure.

FIG. **6** is a flowchart **600** of a process for aligning include offsets, according to one embodiment of the present disclosure.

FIG. **7** is a flowchart **700** of a process for defining and transmitting a metadata stream, according to one embodiment of the present disclosure.

FIG. **8** is a block diagram of a computing system **800** that performs data replication between heterogeneous storage servers, according to one embodiment of the present disclosure.

FIG. **9** is a block diagram of a network system **900**, according to one embodiment of the present disclosure.

While the disclosure is susceptible to various modifications and alternative forms, specific embodiments of the disclosure are provided as examples in the drawings and detailed description. It should be understood that the drawings and detailed description are not intended to limit the disclosure to the particular form disclosed. Instead, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the disclosure as defined by the appended claims.

DETAILED DESCRIPTION

Introduction

Generally, backup operations may be full or incremental. A full backup operation produces a full backup set or a copy of all data—data that has changed as well as data that is unchanged. An incremental backup operation produces an incremental backup set or a copy of only data that has changed (e.g., since a prior full or incremental backup operation).

Some backup systems offer another option. For example, a synthetic full backup operation consolidates a baseline full backup set and several incremental backup sets into a new full backup set. The new full backup set can then be used for further incremental backup operations. Generally, a new full backup of a given data set is preferable to definitively protect the data set in question.

NetBackup Accelerator, provided by Veritas Technologies, LLC of Mountain View, Calif., can provide full backups for the cost of an incremental backup, and can also create a synthetic full backup in approximately the same time needed to run an incremental backup operation. NetBackup Accelerator can improve the speed of a synthetic full backup operation by combining changed data with a list of data that has already been backed up during a previous full or incremental backup operation, and deduplicating this combination of data—without reading backup images and/or creating a new backup image. Therefore, by independently tracking and deduplicating data that has already been backed up, NetBackup Accelerator only requires changed data to create a synthetic full backup set in roughly the same time it takes to run an incremental backup operation.

NetBackup Accelerator implements a platform and file system independent track log to detected changed data and sends the changed (or modified) data (segments) to a media server. NetBackup Accelerator can also deduplicate data and send unique data (e.g., changed and/or modified data segments) directly to a storage server. NetBackup Accelerator can be used to perform backup and recovery in open storage environments.

Unfortunately, as previously noted, partial segment inclusion causes synthetic backup speed degradation in deduplication based storage systems. For example, if a backup operation starts in the middle of a data segment (hereinafter "segment"), partial segment inclusion typically requires at least the following steps: (1) data in the buffer to be flushed as a new segment, (2) the partial segment to be read from backend storage, (3) the partial segment to be flushed as another new segment, and (4) any intervening segment references to be copied to a target image (e.g., a current backup image). These steps typically have to be repeated for every partial data segment (e.g., for all head portion and tail portion of the first and last segments of an include operation). As will be appreciated, these extraneous steps can

cause performance-related problems with respect to backup and restore operations in client-side deduplication storage systems.

For example, from a backup operation perspective, reading data from backend storage is very slow compared to reading data from front end storage (e.g., a virtual disk), particularly if partial segments are being read to form a new small segment. For example, if multiple small files have been changed and/or modified, multiple small includes (e.g., in include operations) will slow down backup performance significantly. In addition, splitting new segments (e.g., into smaller segments) requires fingerprint recalculation, compression, encryption, and data transmission—a laborious process to say the least.

From a restore operation perspective, multiple segments with the same total data size means worse locality, resulting in slower restore speed. Splitting segments in this manner can affect segment distribution, causing rehydration or tape out problems. For example, fragmentation of data backed up in a synthetic full backup can negatively affect rehydration performance.

Disclosed herein are methods, systems, and processes to improve backup and restore performance in deduplication storage environments. One technology that can employ such methods, systems, and processes is NetBackup Accelerator, provided by Veritas Technologies, LLC of Mountain View, Calif.

Examples of Client-Side Deduplication Storage Systems

FIG. **1** is a block diagram **100** of a deduplication storage system, according to one embodiment. As shown in FIG. **1**, such a system includes a master server **105**, a media server **115**, and a client **150**. Master server **105**, media server **115**, and client **150** can be any of a variety of different types of computing devices, including a server, personal computing device, laptop computer, cellular phone, or the like.

Master server **105** implements a backup manager **110**. Media server **115** has access to backup image metadata **120** and implements a backup application **125**, a storage pool manager **130**, and a backup stream manager **135**. Media server **115** is coupled to backup storage system **140**. Backup storage system **140** stores one or more backup images (e.g., backup image **145**).

Client **150** implements a metadata stream receiver **155** and stores a temporary file **160**. Temporary file **160** includes backup image metadata **120** (e.g., generated and/or accessed by media server **115**). Client **150** also includes a backup agent **165** that implements an include offset aligner **170**, a partial segment sender **175**, and can include a changed block tracker. Client **150** is coupled to local storage system **180**. Local storage system **180** stores local data **185**.

Media server **115** and client **150** are communicatively coupled to each other via a network **190**. Any type of network and/or interconnection other than network **190** (e.g., the Internet) can be used to facilitate communication between media server **115** and client **150**.

FIG. **2**A is a block diagram **200**A of a computing system that performs client-side deduplication, according to one embodiment. FIG. **2**A includes a server **205**, a proxy server **225**, master server **105**, and media server **115**. Server **205** implements virtual machines **210**(**1**)-(N), and includes a changed block tracker **215**, a file system **220**, and local storage system **180** (which stores local data **185**). Server **205** and media server **115** can be communicatively coupled to each other via a network **190**, or any type of network and/or interconnection.

Proxy server **225**, which in some embodiments is implemented by server **205** (e.g., on a client-side), includes an accelerator **230** and a deduplication engine **235**. In addition, proxy server **225** can be implemented as client **150** (as shown in FIG. **1**) and can implement metadata stream receiver **155**, temporary file **160**, and backup agent **165**. Master server **105** includes a catalog **240** and a state file **245**. It will be appreciated that, while state file **245** is depicted as being maintained at master server **105**, such need not necessarily be the case. State file **245** can be maintained on media server **115** or at any location in the computing system of FIGS. **1** and **2**A. Media server **115** includes synthesis engine **250** and backup engine **255**. Backup engine **255** is coupled to backup storage system **140**, which can be used to store one or more backup images (e.g., backup image **145**) of one or more corresponding backup sets.

To create a synthetic full back up set, accelerator **230** first requests and obtains changed storage units (e.g., for each virtual disk included in a backup operation) from virtual machine **210**(**1**). Virtual machine **210**(**1**) running on server **205** can track storage units (e.g., disk sectors) that have changed, using changed block tracker **215**, for example. Once identified, changed storage units from virtual machine **210**(**1**) are sent to proxy server **225**.

State file **245**, which stores information about each storage unit (e.g., about each extent of data on a virtual disk), is obtained and/or retrieved from master server **105**. In some embodiments, state file **245** can be made available on proxy server **225**, which in this example, functions as a virtual machine proxy host and/or a backup host. State file **245** includes information about storage units which have already been backed up to backup storage system **140** by backup engine **255** (e.g., as part of a previous full or incremental backup). Based on the information in state file **245**, accelerator **230** combines changed storage units with a list of storage units that have been already backed up. Accelerator **230** then transfers this combined data and information to deduplication engine **235**. Once this combined data is deduplicated (e.g., to remove storage units that have been already and/or previously backed up), a synthetic full backup is generated on media server **115** (e.g., using synthesis engine **250**). State file **245** is then updated by media server **115** and transferred to master server **105** after the backup of each virtual disk is completed.

It should be noted that accelerator **230** need only generate catalog data for the changed storage units. When media server **115** generates the synthetic full backup (e.g., using synthesis engine **250** as noted above), accelerator **230** transfers catalog information (e.g., information noting the location of the storage units in a backup image) for a full backup to master server **105**. Therefore, a synthetic full backup operation performed using the computing systems of FIGS. **1** and **2**A typically consumes as much catalog space as a traditional full backup, though catalog information can be stored incrementally, as well.

However, since accelerator **230** only requires changed data to create a synthetic full backup set, accelerator **230** can create the synthetic full backup set in approximately the same amount of time it takes to create an incremental backup set—a significant time-saving advantage. Further, by only sending the data and metadata for a full backup occasionally (and just incremental backups in between), such an approach avoids wasteful redundant operations. Unfortunately, and as noted above, partial segment inclusion during the creation of a synthetic full backup set causes synthetic backup speed degradation in deduplication based storage systems of FIGS. **1** and **2**A.

FIG. **2**B is a table **200**B of backup image metadata, according to one embodiment. Backup image metadata **120** is metadata related to and associated with backup image **145** (e.g., a previous backup image such as backup image **145**) stored on backup storage system **140** (e.g., a backend physical storage unit). As shown in FIG. **3**B, backup image metadata **120** identifies a metadata header **260** as well as metadata for each of segments **265**(**1**)-(N) (e.g., segment offset, fingerprint, containerID, and the like).

FIG. **2**C is a block diagram **200**C of a deduplication storage system that performs partial segment inclusion, according to one embodiment. One reason for including partial segments arises if a backup operation starts in the middle of a segment. As shown in FIG. **2**C, a backup stream **270** includes a header **275**(**1**) and data **280**(**1**), and can be represented as a backup image (e.g., a tar image) for a current (or ongoing) backup operation (e.g., backup image **145**). Backup stream **270** is created by backup agent **165** and send to media server **115**.

Data **280**(**1**) in backup stream **270** includes four segment objects in backup image **145**. For example, as shown in FIG. **2**C, data **280**(**1**) is part of segment object **285**(**1**), is part of segment objects **285**(**2**) and **285**(**3**), and is partially part of segment object **285**(**4**). Segment objects **285**(**1**)-(**5**) represent data objects that can be (possibly) deduplicated by deduplication agent **235**. Include operation **290** instructs synthesis engine **250** in media server **115** to "copy or reference" data from a previous backup image or a source backup image (e.g., backup image **145** as shown in FIGS. **1** and **2**A).

If an include operation (e.g., include operation **290**) involves partially referenced segments (e.g., segment object **285**(**1**) and **285**(**4**) as shown in FIG. **2**C), the partially referenced segment has to be included my media server **115** (e.g., during a synthetic full backup operation). As previously noted, such an inclusion requires at least the following steps: (1) data in the buffer (e.g., the upper portion of segment object **285**(**1**)) has to be flushed as a new segment (e.g., segment object **285**(**1**)'), (2) the partial segment (e.g., the lower portion of segment object **285**(**1**)) has to be read from backend storage (e.g., from backup storage system **140**), (3) the partial segment (e.g., the lower portion of segment object **285**(**1**)) has to be flushed as another new segment (e.g., segment object **285**(**1**)"), and (4) any intervening segment references (e.g., segment objects **285**(**2**) and **285**(**3**)) have to be copied to a target backup image (e.g., synthesized backup image **295**). These steps typically have to be repeated for every partial data segment (e.g., segment object **285**(**4**)).

As will be appreciated, these laborious steps can cause performance related problems and degradations with respect to backup and restore operations in client-side deduplication storage systems at least because: (1) reading data from backup storage system **140** is very slow compared to reading data from local storage system **180**, (2) reading back partial segments to form a new small segment (e.g., segment object **285**(**1**)") requires fingerprinting, compression, encryption, and transmission of segments, and (3) splitting data into more segments (e.g., segment object **285**(**1**)' and **285**(**1**)" results in worse data locality (e.g., because of the creation of multiple small segments with the same total data size). Issues related to rehydration as well as tape out problems can also occur.

Example of Defining and Transmitting a Metadata Stream

As noted with reference to FIG. **2**B, backup image metadata **120** is metadata related to and associated with backup image **145** (e.g., a previous backup image such as backup image **145**) stored on backup storage system **140** (e.g., a backend physical storage unit). As shown in FIG. **3**B, backup image metadata **120** identifies a metadata header **260** as well as metadata for each of segments **265**(**1**)-(N) (e.g., segment offset, fingerprint, containerID, and the like).

In one embodiment, a metadata stream of a previous backup image (e.g., backup image **145**) is defined, and is then transmitted from media server **115** to backup agent **165** at the start of a backup operation. For example, media server **115** can instruct storage pool manager **130** to retrieve metadata associated with backup image **145** from backup storage system **140**. This metadata can be stored as backup image metadata **120** by media server **115** and sent (or transmitted) to backup agent **165** in client **150** via network **190**.

Example of Converting Offsets of Segments

FIG. **3**A is a block diagram **300**A of a backup agent and a media server, and FIG. **3**B is a block diagram **300**B of a media server, according to some embodiments. Backup agent **165** generates backup stream **270** and transmits backup stream **270** to media server **115**. Media server **115** splits backup stream **270** into backup image metadata **120** (e.g., PD .hdr) and backup image **145** (e.g., PD .img). In one embodiment, the image format for backup stream **270** is "tar" (e.g., shown as archive stream **305** in FIG. **3**B).

In this example, if a particular file needs to be backed up, a tar header is created for the file (e.g., header file **310**) based on the file's statistics information (e.g., file size, ownership, and the like). In this example, archive stream **305** (e.g., backup stream **270**) can be split by a storage server (e.g., media server **115**) into header file **310** (e.g., PD .hdr) and a data image file (e.g., PD .img). As shown in FIG. **3**B, header file **310** includes archive header(s) **320** and data image file **315** includes backup data **325**.

FIG. **3**C is a block diagram **300**C of a backup engine and a backup agent, according to one embodiment. Backup engine **255** implements an offset converter **330**. Because header file **310** and data image file **315** are stored separately, offset converter **330** converts segment offsets of a previous backup image (e.g., backup image **145**) to offsets based on a current backup image (e.g., backup stream **270** or archive stream **305**). Backup agent **255** includes include offset aligner **170** and partial segment sender **175**. Include offset aligner **170** ensures that offsets for alignment are offsets based on backup stream **270** (e.g., archive stream **305**) because backup agent **165** does not have information regarding backup image **145** (e.g., data image file **315**).

As previously noted, metadata associated with a previous backup image is sent from media server **115** to client **150**. In some embodiments, metadata retrieval functionality can be implemented using an Open Storage Technology (OST) interface (e.g., sts_read_metastream). For example, image segment information (e.g., fingerprint, container_id, segment object size, and the like) is extracted by backup engine **255** (implemented in media server **115**), and segment start offsets are calculated by offset converter **330** by accumulating each segment's size. Then, offset converter **330** converts segment offsets based on data image file **315** to offsets based on backup image **145**. The (converted) offsets are segment boundaries, and in one embodiment, can be retrieved using the OST interface (e.g., sts_read_metastream). The (converted) offsets are sent to backup agent **165** as part of the metadata stream from media server **115** to client **150**.

FIG. **3**D is a block diagram **300**D of an offset converter, according to one embodiment. As shown in FIG. **3**D, header file **310** includes header **275**(**1**)-(N). Headers **275**(**1**)-(**5**) are represented as h1-h5 in archive stream **305**. Similarly, data file image **315** includes segment objects **285**(**1**)-(N). Segment objects **285**(**1**)-(**5**) are represented as d1-d5 in archive

stream **305**. Offset converter **300** converts segment offsets based on backup image **145** (e.g., data image file **315** or previous PD .img file) to offsets based on backup stream **270** (e.g., archive stream **305** or a tar image for a current backup operation). Offset converter **300** performs this conversion process at least because header file **310** (e.g., PD .hdr file) and data image file **315** are stored separately. In some embodiments, d1 may include only segment object **285**(**1**). In other embodiments, d1 may include multiple segment objects (e.g., **285**(**1**) and **285**(**2**)).

Example of Aligning Include Offset with Segment Boundary

FIG. **3**E is a block diagram **300**E of an include offset aligner, according to one embodiment. Include offset aligner **170** permits the alignment of an include offset with a segment boundary, for example, to determine which parts need to be transmitted to media server **115** from client **150**. In one embodiment, offsets to be included in a target image (e.g., synthesized backup image **295**) for a current backup (e.g., backup stream **270**) are aligned.

Because backup agent **165** does not know how a previous backup image (e.g., backup image **145**) is stored on a storage server (e.g., media server **115**), it is possible that an include operation to copy of reference data from a previous backup image can start or end in the middle of a segment object (e.g., the partial segment inclusion problem as shown in FIG. **2**C). Therefore, include offset aligner **170** modifies the include offset to avoid a reference to a partial segment. For example, as shown in FIG. **3**E, include offset aligner **170** moves include start **335** in backup stream **270** from the middle of segment object **285**(**1**) (which is a partially referenced segment object) to segment object **285**(**2**) as include new start **340**. In this manner, include offset aligner can identify and instruct partial segment sender **175** to retransmit parts of a partially referenced segment object from local storage system **180** to media server **115**.

Examples of Avoiding and Retransmitting Partially Referenced Segments

FIG. **3**F is a block diagram **300**F a deduplication storage system that avoids partial segment reference and instead retransmits the partially referenced segment, according to one embodiment. First, backup and restore job manager **345** sends a request to backup and restore manager **350** to start a backup operation. Backup engine **255** in backup and restore manager **350** initiates a backup operation by requesting and then receiving backup image metadata **120** from metadata read interface **330** (e.g., an OST interface). Metadata read interface **330** receives backup image metadata **120** from storage pool manager **130** which implements a media server deduplication pool **370**, and is communicatively coupled to backend physical storage unit **375**, which contains backup image **145**.

Backup and restore manager **350** generates a metadata stream **380** with backup image metadata **120** and sends metadata stream **380** containing backup image metadata **120** to communications manager **355**. Communications manager **355** receives metadata stream **380** from media server **115** via metadata stream receiver **155**, and transmits the metadata stream **380** along with backup image metadata **120** to backup agent **165**.

FIG. **3**G is a block diagram **300**G of an include offset aligner, according to one embodiments. Metadata stream **380** that is received by backup agent **165** includes one or more data segment offsets that are associated with segments of a previous backup image (e.g., backup image **145** stored on backend physical storage unit **375** or backup storage system **140**). The one or more segment offsets indicate segment boundaries. Once metadata stream **380** is received by backup agent **165**, include offset aligner **170** determines an offset (e.g., a start offset or an end offset) for an include operation (e.g., an operation to "copy or reference" data from a previous backup image such as backup image **145**). In this example, the include operation references one or more segments, and is part of a request to perform a backup operation. Backup agent **165** then performs the backup operation by modifying the include operation using include offset aligner **170**, if the offset involves one or more partial data segments.

FIG. **3**H is a block diagram **300**H of a partial segment sender, according to one embodiment. For example, include offset aligner **170** can align the offset of the include operation with a data segment boundary by moving the start offset forward from a first data segment if the first data segment includes a partial data segment, and/or moving the end offset backward from a second data segment if the second data segment includes another partial data segment. Backup agent **165** then performs the modified include operation as part of the backup operation by generating a modified backup stream, and partial segment sender **175** transmits the partial data segment instead of the first data segment to media server **115** as part of the modified backup stream if the first data segment includes the partial data segment, and/or transmits another partial data segment instead of the second data segment to the media server as part of the modified backup stream if the second data segment includes another partial data segment. Include offset aligner **170** avoids the need for inclusion of partially referenced segments, and partial segment sender **175** avoids the need for retrieval of such partial segments from backend storage.

FIG. **3**I is a block diagram **300**I of a deduplication storage system that avoids partial segment inclusion, according to one embodiment. Include offset aligner **170** aligns the include offset with a segment boundary to determine which parts (e.g., of the partially referenced segment) needs to be retransmitted from client **150** to media server **115**. This alignment process is performed for both the head and tail segments of an include operation as shown in FIG. **3**I. In addition, partial segment sender **175** retransmits the partial segments (e.g., partially referenced portions of segment objects **285**(**1**) and **285**(**4**)) as part of backup stream **270** to backup stream manager **135**. Partial segment receiver **135** then combines the retransmitted partial segments with their corresponding parts prior to performing deduplication.

Processes to Improve Performance of Deduplication Storage Systems

FIG. **4**A is a flowchart **400**A of a process for identifying a partially referenced data segment, according to one embodiment. The process begins at **405** by receiving a metadata stream from a media server. At **410**, the process accesses an archive stream, and at **415**, determines a start offset and an end offset of an include operation. At **420**, the process determines whether the start offset or the end offset involve a partially referenced data segment.

If the start offset or the end or the end offset do not involve a partially referenced data segment, the process, at **425**, performs the include operation. However, if the start offset or the end offset involve a partially referenced data segment, the process, at **430**, performs a modified include operation. At **435**, the process determines if there is another backup or restore request. If there is another backup or restore request, the process loops to **405**. Otherwise, the process ends.

FIG. **4**B is a flowchart **400**B of a process for avoiding partial segment inclusion, according to one embodiment. The process begins at **440** by determining whether a backup or restore operation has been started. If no backup or restore operation has been started, the process loops back to **440**. However, if a backup or restore operation has been started, the process, at **445**, receives an archive stream with an original include operation. At **450**, the process accesses an metadata stream, and at **455**, determines a start offset or an end offset of partially referenced data segment(s).

At **460**, the process aligns an include offset by moving the start offset forward or the end offset backward, and at **465**, the process generates a modified backup stream. At **470**, the process includes the partially referenced data segment(s), and at **475**, the process sends the modified backup stream as well as the partially referenced data segment(s) to a media server. At **480**, the process determines if there is another backup or restore operation. If there is another backup or restore operation, the process loops back to **445**. Otherwise, the process ends.

FIG. **5** is a flowchart **400** of a process for generating a modified backup stream, according to one embodiment. The process begins at **505** by detecting a command line flag. At **510**, the process loads metadata information from a temporary file, and at **515**, the process checks a start offset and an end offset of an include operation. At **520**, the process aligns an include offset with segment boundaries for offsets to be included in a backup image.

At **525**, the process modifies the include operation to avoid the partial data segment reference, and at **530**, the process generates a modified backup stream. At **535**, the process includes the partially referenced data segment(s) in the modified backup stream, and at **540**, the process sends the modified backup stream along with the referenced partial data segment(s) to a media server. At **545**, the process determines if there is another backup or restore operation. If there is another backup or restore operation, the process loops back to **505**. Otherwise, the process ends.

FIG. **6** is a flowchart **600** of a process for aligning include offsets, according to one embodiment. The process begins at **605** by analyzing an include operation. At **610**, the process determines whether a start offset (e.g., inc_start) or an end offset (e.g., inc_end) in the include operation falls in the middle of a data segment. If the start offset or the end offset does not fall in the middle of a data segment, the process, at **615**, performs the include operation normally and loops to **635**. However, if the start offset or the end offset does fall in the middle of a data segment, the process, at **620**, increases inc_start to move the start offset forward and/or decreases inc_end to move the end offset backward.

At **625**, the process includes complete data segment reference(s) from a backup image, and at **630**, the process sends (or transfers) only the partial data segment(s) of the partial data segment reference(s) with a (modified) backup stream. At **635**, the process determines if there is another backup stream. If there is another backup stream, the process loops back to **605**. Otherwise, the process ends.

FIG. **7** is a flowchart **700** of a process for defining and transmitting a metadata stream, according to one embodiment. The process begins at **705** by determining that a backup operation has been started by a master server. At **710**, the process converts data segment offset(s) of a (previous) data image to data segment offset(s) based on an archive stream. At **715**, the process defines a metadata stream of the (previous) data image based on the conversion, and at **720**, the process transmits the metadata stream to a client at the beginning of the backup operation. At **725**, the process determines if there is another backup operation. If there is another backup operation, the process loops back to **705**. Otherwise, the process ends.

Therefore, it will be appreciated that the methods, systems, and processes described herein improve backup and restore performance in deduplication storage environments.

Example Computing Environment

FIG. **8** is a block diagram of a computing system **800** that improves backup and restore performance in deduplication storage environments, according to one embodiment. Computing system **800** (e.g., master server **105**, media server **115**, client **150**, server **205**, and/or proxy server **225**) and broadly represents any single or multi-processor computing device or system capable of executing computer-readable instructions. Examples of computing system **800** include, without limitation, any one or more of a variety of devices including workstations, personal computers, laptops, client-side terminals, servers, distributed computing systems, handheld devices (e.g., personal digital assistants and mobile phones), network appliances, storage controllers (e.g., array controllers, tape drive controller, or hard drive controller), and the like.

In its most basic configuration, computing system **800** may include at least one processor **855** and a memory **860**. By executing the software that implements a backup agent **165**, computing system **800** becomes a special purpose computing device that is configured to improve backup and restore performance in deduplication storage environments.

Processor **855** generally represents any type or form of processing unit capable of processing data or interpreting and executing instructions. In certain embodiments, processor **855** may receive instructions from a software application or module. These instructions may cause processor **855** to perform the functions of one or more of the embodiments described and/or illustrated herein. For example, processor **855** may perform and/or be a means for performing all or some of the operations described herein. Processor **855** may also perform and/or be a means for performing any other operations, methods, or processes described and/or illustrated herein.

Memory **860** (e.g., memory of master server **105**, media server **115**, client **150**, server **205**, and/or proxy server **225**) generally represents any type or form of volatile or non-volatile storage devices or mediums capable of storing data and/or other computer-readable instructions. Examples include, without limitation, random access memory (RAM), read only memory (ROM), flash memory, or any other suitable memory device. Although not required, in certain embodiments computing system **800** may include both a volatile memory unit and a non-volatile storage device. In one example, program instructions implementing backup agent **165** may be loaded into memory **860**.

In certain embodiments, computing system **800** may also include one or more components in addition to processor **855** and/or memory **860**. For example, as illustrated in FIG. **8**, computing system **800** may include a memory controller **820**, an Input/Output (I/O) controller **835**, and a communication interface **845**, each of which may be interconnected via a communication infrastructure **805**. Communication infrastructure **805** generally represents any type or form of infrastructure capable of facilitating communication between one or more components of a computing device. Examples of communication infrastructure **805** include, without limitation, a communication bus (such as an Industry Standard Architecture (ISA), Peripheral Component Interconnect (PCI), PCI express (PCIe), or similar bus) and a network.

Memory controller **820** generally represents any type/form of device capable of handling memory or data or controlling communication between one or more components of computing system **800**. In certain embodiments memory controller **820** may control communication between processor **855**, memory **860**, and I/O controller **835** via communication infrastructure **805**. In certain embodiments, memory controller **820** may perform and/or be a means for performing, either alone or in combination with other elements, one or more of the operations or features described and/or illustrated herein.

I/O controller **835** generally represents any type or form of module capable of coordinating and/or controlling the input and output functions of an appliance and/or a computing device. For example, in certain embodiments I/O controller **835** may control or facilitate transfer of data between one or more elements of computing system **800**, such as processor **855**, memory **860**, communication interface **845**, display adapter **815**, input interface **825**, and storage interface **840**.

Communication interface **845** broadly represents any type or form of communication device or adapter capable of facilitating communication between computing system **800** and one or more other devices. Communication interface **845** may facilitate communication between computing system **800** and a private or public network including additional computing systems. Examples of communication interface **845** include, without limitation, a wired network interface (such as a network interface card), a wireless network interface (such as a wireless network interface card), a modem, and any other suitable interface. Communication interface **845** may provide a direct connection to a remote server via a direct link to a network, such as the Internet, and may also indirectly provide such a connection through, for example, a local area network (e.g., an Ethernet network), a personal area network, a telephone or cable network, a cellular telephone connection, a satellite data connection, or any other suitable connection.

Communication interface **845** may also represent a host adapter configured to facilitate communication between computing system **800** and one or more additional network or storage devices via an external bus or communications channel. Examples of host adapters include, Small Computer System Interface (SCSI) host adapters, Universal Serial Bus (USB) host adapters, Institute of Electrical and Electronics Engineers (IEEE) 1394 host adapters, Serial Advanced Technology Attachment (SATA), Serial Attached SCSI (SAS), and external SATA (eSATA) host adapters, Advanced Technology Attachment (ATA) and Parallel ATA (PATA) host adapters, Fibre Channel interface adapters, Ethernet adapters, or the like. Communication interface **845** may also allow computing system **800** to engage in distributed or remote computing (e.g., by receiving/sending instructions to/from a remote device for execution).

As illustrated in FIG. **8**, computing system **800** may also include at least one display device **810** coupled to communication infrastructure **805** via a display adapter **815**. Display device **810** generally represents any type or form of device capable of visually displaying information forwarded by display adapter **815**. Similarly, display adapter **815** generally represents any type or form of device configured to forward graphics, text, and other data from communication infrastructure **805** (or from a frame buffer, as known in the art) for display on display device **810**. Computing system **800** may also include at least one input device **830** coupled to communication infrastructure **805** via an input interface **825**. Input device **830** generally represents any type or form of input device capable of providing input, either computer or human generated, to computing system **800**. Examples of input device **830** include a keyboard, a pointing device, a speech recognition device, or any other input device.

Computing system **800** may also include storage device **850** coupled to communication infrastructure **805** via a storage interface **840**. Storage device **850** generally represents any type or form of storage devices or mediums capable of storing data and/or other computer-readable instructions. For example, storage device **850** may include a magnetic disk drive (e.g., a so-called hard drive), a floppy disk drive, a magnetic tape drive, an optical disk drive, a flash drive, or the like. Storage interface **840** generally represents any type or form of interface or device for transferring and/or transmitting data between storage device **850**, and other components of computing system **800**. Storage device **850** may be configured to read from and/or write to a removable storage unit configured to store computer software, data, or other computer-readable information. Examples of suitable removable storage units include a floppy disk, a magnetic tape, an optical disk, a flash memory device, or the like. Storage device **850** may also include other similar structures or devices for allowing computer software, data, or other computer-readable instructions to be loaded into computing system **800**. For example, storage device **850** may be configured to read and write software, data, or other computer-readable information. Storage device **850** may also be a part of computing system **800** or may be separate devices accessed through other interface systems.

Many other devices or subsystems may be connected to computing system **800**. Conversely, all of the components and devices illustrated in FIG. **8** need not be present to practice the embodiments described and/or illustrated herein. The devices and subsystems referenced above may also be interconnected in different ways from that shown in FIG. **8**.

Computing system **800** may also employ any number of software, firmware, and/or hardware configurations. For example, one or more of the embodiments disclosed herein may be encoded as a computer program (also referred to as computer software, software applications, computer-readable instructions, or computer control logic) on a computer-readable storage medium. Examples of computer-readable storage media include magnetic-storage media (e.g., hard disk drives and floppy disks), optical-storage media (e.g., CD- or DVD-ROMs), electronic-storage media (e.g., solid-state drives and flash media), and the like. Such computer programs can also be transferred to computing system **800** for storage in memory via a network such as the Internet or upon a carrier medium.

The computer-readable medium containing the computer program may be loaded into computing system **800**. All or a portion of the computer program stored on the computer-readable medium may then be stored in memory **860** and/or various portions of storage device **850**. When executed by processor **855**, a computer program loaded into computing system **800** may cause processor **855** to perform and/or be a means for performing the functions of one or more of the embodiments described and/or illustrated herein. Additionally or alternatively, one or more of the embodiments described and/or illustrated herein may be implemented in firmware and/or hardware. For example, computing system **800** may be configured as an application specific integrated circuit (ASIC) adapted to implement one or more of the embodiments disclosed herein.

Example Networking Environment

FIG. **9** is a block diagram of a networking system **900**, according to one embodiment. In certain embodiments, network-attached storage (NAS) devices may be configured to communicate with master server **105**, media server **115**, client **150**, server **205**, and/or proxy server **225** using various protocols, such as Network File System (NFS), Server Message Block (SMB), or Common Internet File System (CIFS). Network **190** generally represents any type or form of computer network or architecture capable of facilitating communication between master server **105**, media server **115**, client **150**, server **205**, and/or proxy server **225**.

In certain embodiments, a communication interface, such as communication interface **845** in FIG. **8**, may be used to provide connectivity between master server **105**, media server **115**, client **150**, server **205**, and/or proxy server **225**, and network **190**. It should be noted that the embodiments described and/or illustrated herein are not limited to the Internet or any particular network-based environment. For example, network **190** can be a Storage Area Network (SAN).

In one embodiment, all or a portion of one or more of the disclosed embodiments may be encoded as a computer program and loaded onto and executed by master server **105**, media server **115**, client **150**, server **205**, and/or proxy server **225**, or any combination thereof. All or a portion of one or more of the embodiments disclosed herein may also be encoded as a computer program, stored master server **105**, media server **115**, client **150**, server **205**, and/or proxy server **225**, and distributed over network **190**.

In some examples, all or a portion of master server **105**, media server **115**, client **150**, server **205**, and/or proxy server **225** may represent portions of a cloud-computing or network-based environment. Cloud-computing environments may provide various services and applications via the Internet. These cloud-based services (e.g., software as a service, platform as a service, infrastructure as a service, etc.) may be accessible through a web browser or other remote interface.

Various functions described herein may be provided through a remote desktop environment or any other cloud-based computing environment. In addition, one or more of the components described herein may transform data, physical devices, and/or representations of physical devices from one form to another. For example, client **150** may transform the behavior of media server **115** in order to cause media server **115** to improve backup and restore performance in deduplication storage environments.

It should be noted that in some situations, scenarios, and embodiments, partial segments are created because only part of a segment is changed. For example, NetBackup Accelerator's changed block tracker **215** tracks changed data in terms of changed blocks—not changed segments. Therefore, changed block tracker **215** has information only regarding changed blocks, not changed segments. Consequently, because blocks are smaller than segments, changed block tracker **215** may send (e.g., during a backup operation) only some of the blocks of what is actually a segment (thus, only a partial segment).

Although the present disclosure has been described in connection with several embodiments, the disclosure is not intended to be limited to the specific forms set forth herein. On the contrary, it is intended to cover such alternatives, modifications, and equivalents as can be reasonably included within the scope of the disclosure as defined by the appended claims.

What is claimed is:

1. A system comprising:

one or more processors; and

a memory coupled to the one or more processors, wherein the memory stores program instructions executable by the one or more processors to
perform a backup operation, comprising further program instructions executable by the one or more processors to
send a request for an existing metadata stream, wherein
the existing metadata stream comprises a plurality of data segment offsets associated with a plurality of data segments of a previous backup image,
the previous backup image was created prior to the backup operation, and
the plurality of data segment offsets indicate a plurality of data segment boundaries,
receive the existing metadata stream,
determine an offset for an include operation, wherein
the offset is one of a start offset or an end offset,
the include operation references one or more data segments of the plurality of data segments,
the include operation is part of a request to perform the backup operation,
at least one data segment is to be included in the backup operation as a result of the include operation, and
the at least one data segment was not in the previous backup image at the offset,
determine whether the include operation will result in a data segment of the one or more data segments becoming one or more partial data segments, wherein
the determining is based, at least in part, on the existing metadata stream and the offset, and
in response to a determination that the include operation will result in the data segment of the one or more data segments becoming the one or more partial data segments, create a modified include operation, wherein
the further program instructions executable by the one or more processors to create comprise program instructions executable by the one or more processors to
modify the include operation to include the one or more partial data segments with the at least one data segment,
determine whether the data segment is a first data segment or a last data segment of the one or more data segments,
in response to a determination that the data segment is a first data segment,
align the offset of the include operation with a data segment boundary of the plurality of data segment boundaries, such that a data segment boundary of a partial data segment of the one or more partial data segments are aligned on a first data segment boundary of the plurality of data segment boundaries, or
in response to a determination that the data segment is a first data segment,
align the offset of the include operation with the data segment boundary of the plurality of data segment boundaries, such that the data segment boundary of a partial data segment of the one or more partial data segments are aligned on a last data segment boundary of the plurality of data segment boundaries.

2. The system of claim **1**, wherein
the existing metadata stream represents the previous backup image in its entirety, and

the one or more partial data segments are aligned by aligning the offset of the include operation with a data segment boundary of the plurality of data segment boundaries.

3. The system of claim **2**, wherein the further program instructions executable by the one or more processors to align comprise program instructions executable to:
move the start offset forward, if the first data segment of the one or more data segments comprises the partial data segment, or
move the end offset backward, if the last data segment of the one or more data segments comprises the partial data segment.

4. The system of claim **3**, further comprising program instructions executable by the one or more processors to:
generate a modified backup stream by performing the modified include operation as part of the backup operation.

5. The system of claim **4**, further comprising program instructions executable by the one or more processors to:
transmit the partial data segment instead of the first data segment to a media server, as part of the modified backup stream, if the first data segment of the one or more data segments comprises the partial data segment; and
transmit the partial data segment instead of the last data segment to a media server, as part of the modified backup stream, if the last data segment of the one or more data segments comprises the partial data segment.

6. A method comprising:
performing a backup operation, comprising
sending a request for an existing metadata stream, wherein
the existing metadata stream comprises a plurality of data segment offsets associated with a plurality of data segments of a previous backup image,
the previous backup image was created prior to the backup operation, and
the plurality of data segment offsets indicate a plurality of data segment boundaries,
receiving the existing metadata stream,
determining an offset for an include operation, wherein
the offset is one of a start offset or an end offset,
the include operation references one or more data segments of the plurality of data segments,
the include operation is part of a request to perform the backup operation,
at least one data segment is to be included in the backup operation as a result of the include operation, and
the at least one data segment was not in the previous backup image at the offset,
determining whether the include operation will result in a data segment of the one or more data segments becoming one or more partial data segments, wherein
the determining is based, at least in part, on the existing metadata stream and the offset, and
in response to a determination that the include operation will result in the data segment of the one or more data segments becoming the one or more partial data segments, creating a modified include operation, wherein the creating comprises
modifying the include operation to include the one or more partial data segments with the at least one data segment,

determining whether the data segment is a first data segment or a last data segment of the one or more data segments,

in response to a determination that the data segment is a first data segment,

the modifying aligns the offset of the include operation with a data segment boundary of the plurality of data segment boundaries, such that a data segment boundary of a partial data segment of the one or more partial data segments are aligned on a first data segment boundary of the plurality of data segment boundaries, or

in response to a determination that the data segment is a last data segment,

the modifying aligns the offset of the include operation with the data segment boundary of the plurality of data segment boundaries, such that the data segment boundary of a partial data segment of the one or more partial data segments are aligned on a last data segment boundary of the plurality of data segment boundaries.

7. The method of claim **6**, wherein

the existing metadata stream represents the previous backup image in its entirety, and

the one or more partial data segments are aligned by aligning the offset of the include operation with a data segment boundary of the plurality of data segment boundaries.

8. The method of claim **7**, wherein the aligning comprises:

moving the start offset forward, if the first data segment of the one or more data segments comprises the partial data segment.

9. The method of claim **8**, wherein the aligning further comprises:

moving the end offset backward, if the last data segment of the one or more data segments comprises the partial data segment.

10. The method of claim **9**, further comprising:

generating a modified backup stream by performing the modified include operation as part of the backup operation.

11. The method of claim **10**, further comprising:

transmitting the partial data segment instead of the first data segment to a media server, as part of the modified backup stream, if the first data segment of the one or more data segments comprises the partial data segment.

12. The method of claim **10**, further comprising:

transmitting the partial data segment instead of the last data segment to a media server, as part of the modified backup stream, if the last data segment of the one or more data segments comprises the partial data segment.

13. A non-transitory computer readable storage medium comprising program instructions executable to:

perform a backup operation, comprising further program instructions executable to send a request for an existing metadata stream, wherein

the existing metadata stream comprises a plurality of data segment offsets associated with a plurality of data segments of a previous backup image,

the previous backup image was created prior to the backup operation, and

the plurality of data segment offsets indicate a plurality of data segment boundaries,

receive the existing metadata stream,

determine an offset for an include operation, wherein

the offset is one of a start offset or an end offset,

the include operation references one or more data segments of the plurality of data segments,

the include operation is part of a request to perform the backup operation,

at least one data segment is to be included in the backup operation as a result of the include operation, and

the at least one data segment was not in the previous backup image at the offset,

determine whether the include operation will result in a data segment of the one or more data segments becoming one or more partial data segments, wherein

the determining is based, at least in part, on the existing metadata stream and the offset, and

in response to a determination that the include operation will result in the data segment of the one or more data segments becoming the one or more partial data segments, create a modified include operation, wherein

the further program instructions executable to create comprise program instructions executable to

modify the include operation to include the one or more partial data segments with the at least one data segment,

determine whether the data segment is a first data segment or a last data segment of the one or more data segments,

in response to a determination that the data segment is a first data segment,

align the offset of the include operation with a data segment boundary of the plurality of data segment boundaries, such that a data segment boundary of a partial data segment of the one or more partial data segments are aligned on a first data segment boundary of the plurality of data segment boundaries, or

in response to a determination that the data segment is a first data segment,

align the offset of the include operation with the data segment boundary of the plurality of data segment boundaries, such that the data segment boundary of a partial data segment of the one or more partial data segments are aligned on a last data segment boundary of the plurality of data segment boundaries.

14. The non-transitory computer readable storage medium of claim **13**, wherein

the existing metadata stream represents the previous backup image in its entirety, and

the one or more partial data segments are aligned by aligning the offset of the include operation with a data segment boundary of the plurality of data segment boundaries.

15. The non-transitory computer readable storage medium of claim **14**, wherein the further program instructions executable to align comprise program instructions executable to:

move the start offset forward, if the first data segment of the one or more data segments comprises the partial data segment, or

move the end offset backward, if the last data segment of the one or more data segments comprises the partial data segment.

16. The non-transitory computer readable storage medium of claim **15**, further comprising program instructions executable to:

generate a modified backup stream by performing the modified include operation as part of the backup operation.

17. The non-transitory computer readable storage medium of claim **16**, further comprising program instructions executable to:

transmit the partial data segment instead of the first data segment to a media server, as part of the modified backup stream, if the first data segment of the one or more data segments comprises the partial data segment; and

transmit the partial data segment instead of the last data segment to a media server, as part of the modified backup stream, if the last data segment of the one or more data segments comprises the partial data segment.

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